MACHINE DESIGN

APRIL 1955

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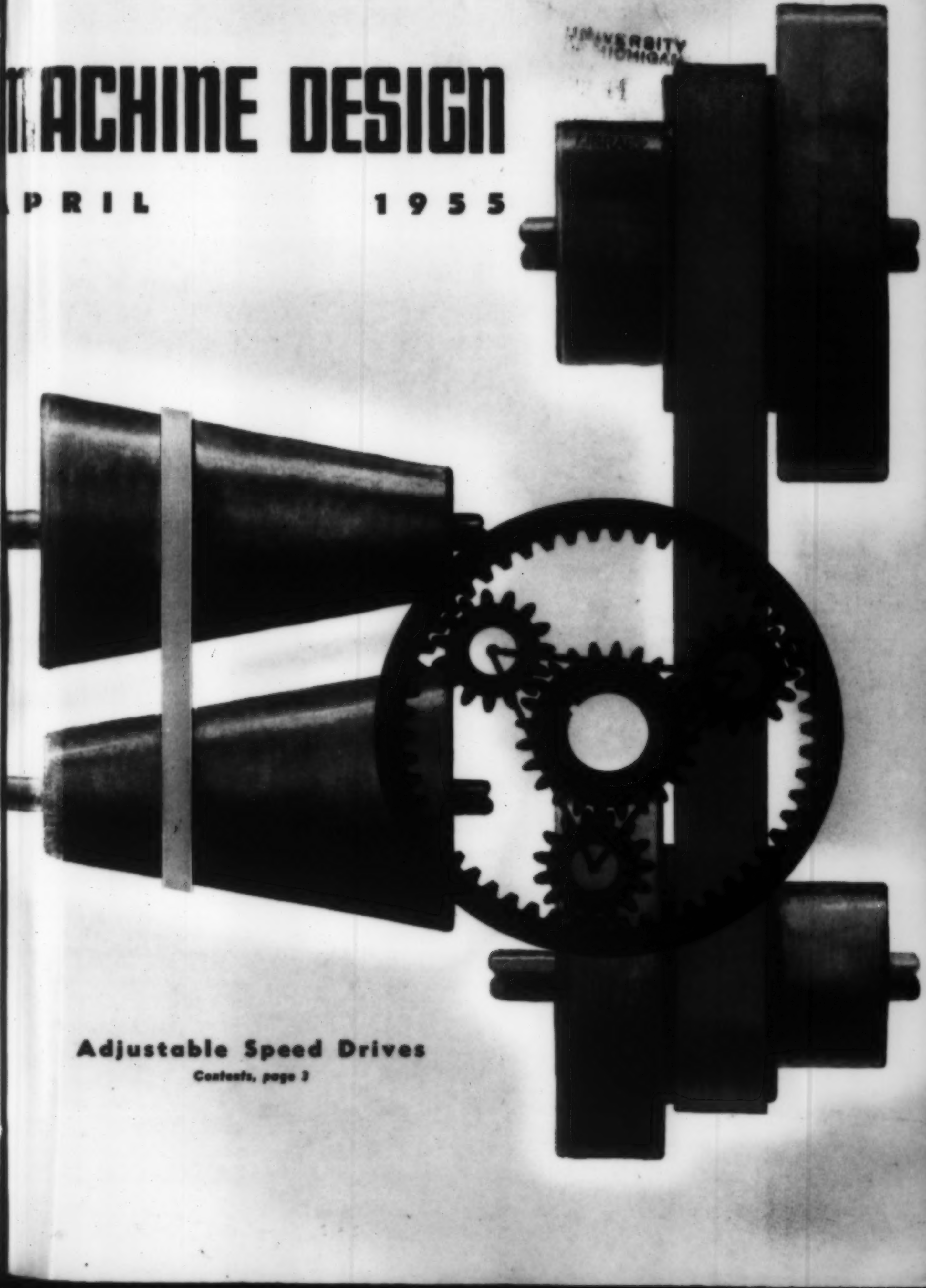

Adjustable Speed Drives

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WARNER & SWASEY
2AC

CUTLER-HAMMER SALUTES THE
WARNER & SWASEY
2AC AUTOMATIC

Warner & Swasey engineering has long held the respect and admiration of machine tool users. This was forcibly demonstrated again when 88 shops ordered the new Warner & Swasey 2AC Automatic Chucking Machine before even the *first* one was ever built. Cutler-Hammer is proud to salute a company that can win and justify such confidence by performance. Nothing else can do it. We are also proud that Cutler-Hammer Motor Control plays a part in this performance. Hundreds of Warner & Swasey 2AC Automatics in use all over the country today commend the engineering judgment that equipped them with Cutler-Hammer Motor Control. CUTLER-HAMMER, Inc., 1310 St. Paul Avenue, Milwaukee 1, Wisconsin. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto, Ont.

THE MARK
CUTLER-HAMMER
MOTOR CONTROL
C-H
OF BETTER MACHINES

THE PROFESSIONAL JOURNAL
FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

APRIL 1955
Vol. 27—No. 4

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Over the Board

Old English Torque

Like most engineers, we are accustomed to hearing such units as "lb-in." for torque, or even "gm-cm." But in miniature bearings the unit gets even smaller; its the "mg-mm." And the latest issue of *Engineering News* put out by Miniature Precision Bearings Inc. reports that, using old English units, a measure of torque might even be the "stone barley corn." As a matter of fact, 1600 mg-mm $= 2.97 \times 10^{-4}$ stone barley corns, a bit of information we're sure *everyone* will want to remember.

Gambling on New Products

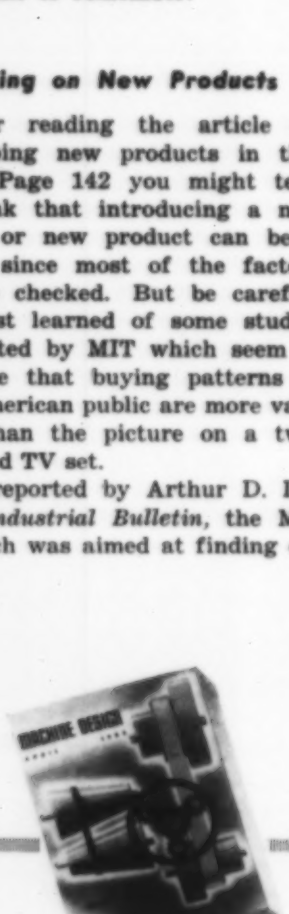
After reading the article on developing new products in this issue, Page 142 you might tend to think that introducing a new model or new product can be a cinch, since most of the factors can be checked. But be careful! We just learned of some studies conducted by MIT which seem to indicate that buying patterns of the American public are more variable than the picture on a two-year-old TV set.

As reported by Arthur D. Little's *Industrial Bulletin*, the MIT research was aimed at finding out what kind of gambling risks the subjects would take. Rules for the laboratory experiment were set up to determine such things as: Did the subject prefer gambling to a sure thing? (Would the consumer try a new product?) Did subjects well acquainted with mathematical probabilities gamble in a mathematically sound way? (Is the consumer's decision to purchase wholly rational?)

Well, 93 per cent of the choices were gambling choices, and within the risk limits of nine to one odds there was no limit beyond which some subjects would not go. Even the subjects with mathematical orientation didn't gamble in a mathematically sound way. Although by no means conclusive, the studies emphasize the relative lack of rationality in consumer reactions.

This Month's Cover

Any resemblance between our front cover this month and an old-fashioned belt-driven sewing machine is purely a figment of the imagination. If you look a second time, you'll find that George Farnsworth has depicted two basic types of mechanical adjustable-speed drives—stepped and stepless—plus a planetary gear set used in some types. Rumors to the contrary, we don't have an article on sewing machines—but we do have a very excellent one by associate editor Leo Spector on mechanical speed adjustment. It's on Page 168.



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STEEL, FOUNDRY, NEW EQUIPMENT DIGEST, AUTOMATION

Published on the seventh of each month. Subscription in the United States, possessions, and Canada: One year $10. Single copies, $1.00. Other countries one year, $20. Copyright 1955 by The Penton Publishing Company. Accepted as Controlled Circulation publication at Cleveland, Ohio.

BPA NBP

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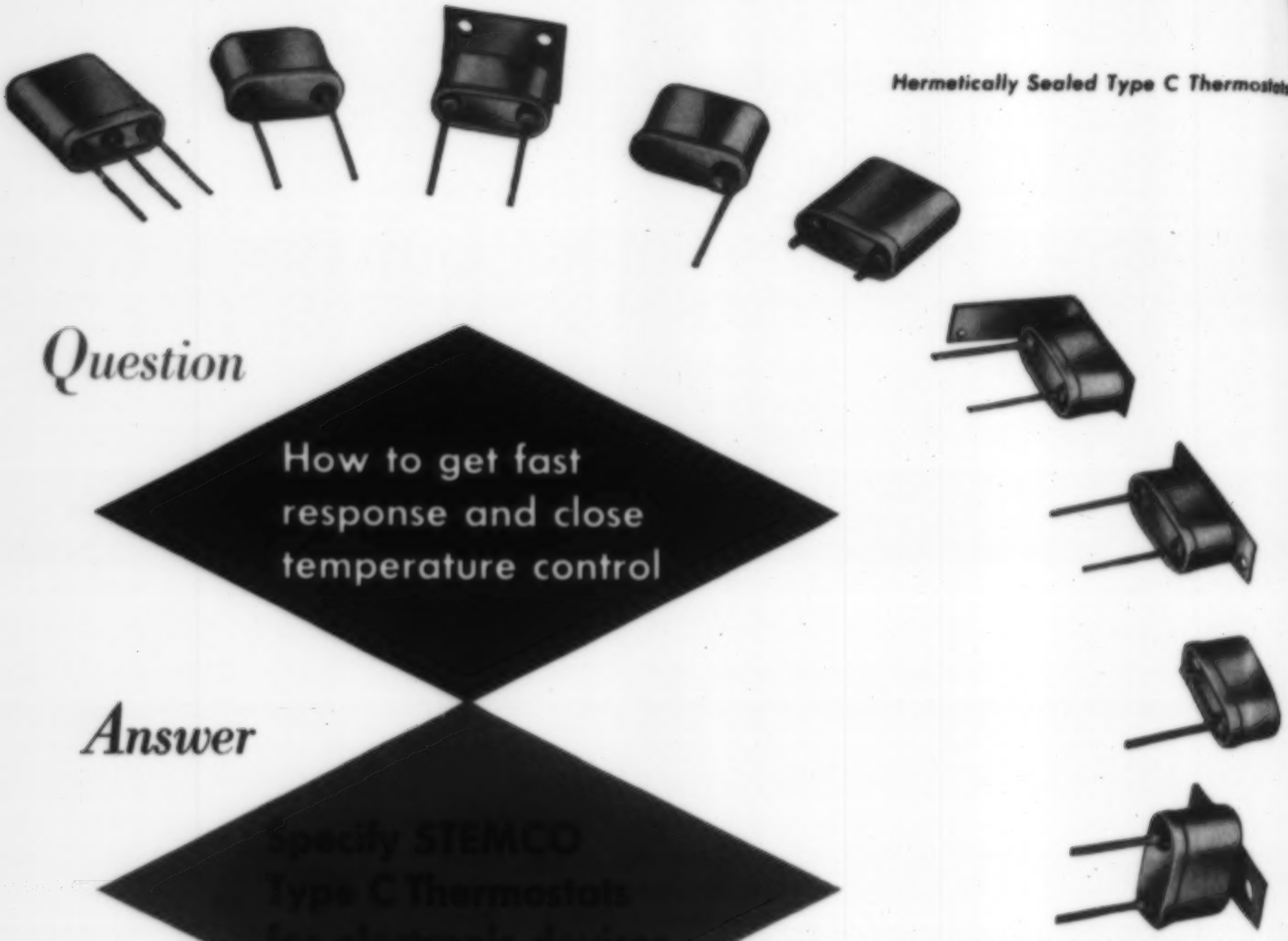


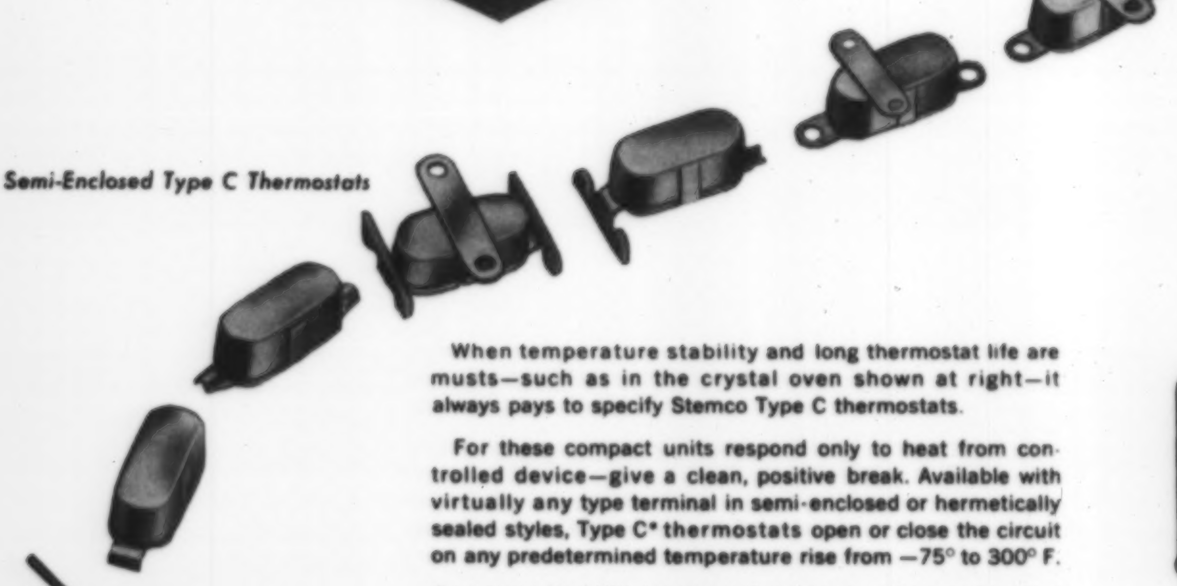
Hermetically Sealed Type C Thermostats

Question

How to get fast response and close temperature control

Answer

Specify STEMCO Type C Thermostats for electronic devices



Semi-Enclosed Type C Thermostats

When temperature stability and long thermostat life are musts—such as in the crystal oven shown at right—it always pays to specify Stemco Type C thermostats.

For these compact units respond only to heat from controlled device—give a clean, positive break. Available with virtually any type terminal in semi-enclosed or hermetically sealed styles, Type C* thermostats open or close the circuit on any predetermined temperature rise from −75° to 300° F.

So insure the life—and performance—of your product with Stemco Type C thermostats. They perform better longer.

AA-662

STEVENS manufacturing company, inc.
Lexington and Mansfield, Ohio

THERMOSTATS

*Patented

Stemco thermostats are used in leading Electronic and Avionic Devices • Computers • Radar • Appliances • Appa

Crystal oven courtesy James Knights Co.

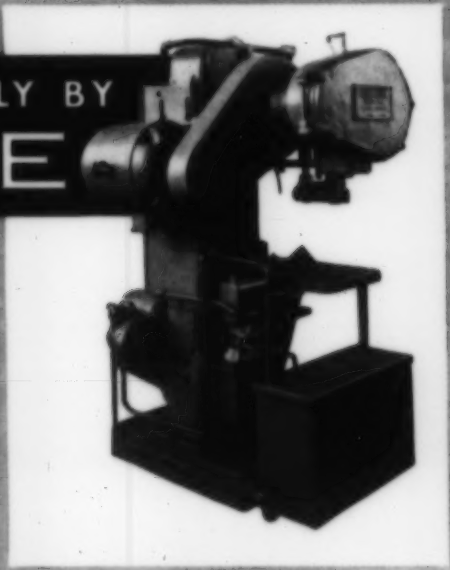
OILGEAR "JK" FEED PUMPS

USED EXTENSIVELY BY MOLINE

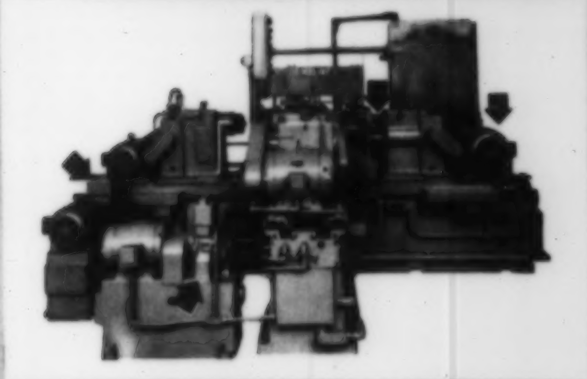
The Moline Tool Company, long established and respected in industry, has used Oilgear Fluid Power Feeds since 1925. Of Oilgear "JK" Fluid Power Feed Pumps used in its machines, Moline says these pumps *combine* the advantages found only in part in various mechanical feeds. Also, the "JK" Feed Pump provides infinitely, steplessly variable speeds; you can easily find the speed best suited to the work or condition of tools. Traverse speed can be as much as 265 times the feed rate. Coarse and fine feed rates are variable over a 20 : 1 range. Cycle time is cut drastically, production increased, costs reduced. Feed rates are maintained accurately despite varying work pressures by a built-in automatic pressure compensator.

"JK" Feed Pumps are simple, compact, electro-hydraulically controlled units, easily installed nearby or remotely. Systems need only a pump with reservoir, a double-acting cylinder, standard control and two easily connected pipes. Eliminating expensive engineering, these units can simplify design, reduce manufacturing cost, improve performance and increase saleability of machines. Manual, semi-automatic or full automatic operation. Available now in 4 sizes. Write for free literature.

THE OILGEAR COMPANY
1568 West Pierce Street
Milwaukee 4, Wis.

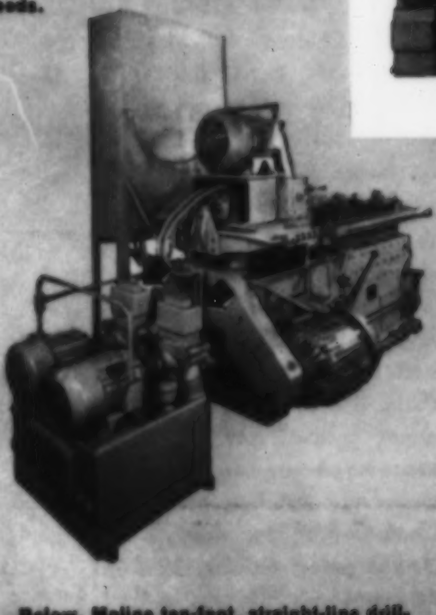


Above, Moline Drilling Machine employing "JK" Feed Pump.

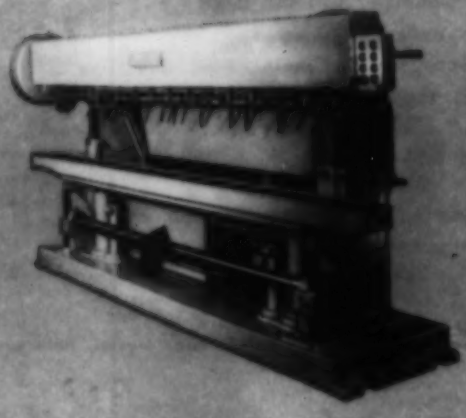


Moline 4-way horizontal boring machine uses 4 Oilgear "JK" Feed Pumps.

Below, Moline special 36-spindle back-spotfacing machine using 2 "JK" units for vertical and horizontal feeds.



Below, Moline ten-foot, straight-line drilling machine using "JK" Feed Pump.



"JK" PUMPS EASILY APPLICABLE TO YOUR MACHINES FOR BETTER PERFORMANCE

JIC

PIONEERS . . . NOW THREE PLANTS FOR FLUID POWER

OILGEAR
Fluid Power

PUMPS, MOTORS, TRANSMISSIONS, CYLINDERS AND VALVES

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NEW DEPARTURES OF TOMORROW

Automatic Lumberjack
—1958?

Even Paul Bunyan couldn't match the pace of this "automatic lumberjack" of the future. It fells, sections and loads trees—all at the push of a button!

The company that launches this wonder will probably look to New Departure for ball bearings. For New Departures have proved their ability to hold moving parts in perfect alignment, cut wear and friction, and work long hours without letup—or upkeep. Above all, New Departure has lived up to its name—being *first* with ball bearing advancements.

So, when improving or designing a product, count on New Departure for the finest ball bearings.

NEW DEPARTURE • DIVISION OF GENERAL MOTORS • BRISTOL, CONNECTICUT

Cool-running chain saw, like every type of power saw in use today, uses New Departure ball bearings for longer life at peak efficiency.

NEW DEPARTURE
BALL BEARINGS

NOTHING ROLLS LIKE A BALL

Engineering News Roundup

Easy Sliding At 2000 Miles per Hour

What happens to friction and sliding surfaces at speeds up to 2000 mph was recently investigated by F. P. Bowden and E. Freitag of the British Institution of Mechanical Engineers. Present tendencies toward higher speeds prompted this study of behavior of metals and other solids sliding at these enormous speeds.

Test results of a steel ball rubbing on a copper surface show that the coefficient of friction drops from about 5 at slow speeds to as low as 0.2 at 1500 mph. Surface wear per unit distance at high speeds was also found to be less than that at low speeds. According to Dr. Bowden, the copper surface layers appeared to approach a molten state. By doing so, the surface layers formed a lubricant. As soon as the rubbing surface was removed, the copper solidified to form a comparatively smooth surface.

To reach the high test speeds, a unique test setup was used. A steel ball was held freely suspended in mid-air by an electromagnet. Current in the magnet was regulated to maintain the ball in a steady position. By applying a rotating magnetic field, the ball was made to rotate. To reduce friction caused by surrounding air, the chamber was evacuated and a rotational speed of over 1 million rpm was reached. Speed of rotation was accurately measured by illuminating the ball and detecting an etched mark on the ball with a photocell.

Three symmetrically placed surfaces were arranged to rub against the ball after it reached a desired speed. One of the surfaces was spring loaded. By measuring the rate of decrease of rotational speed under a known spring load, coefficient of friction was determined.

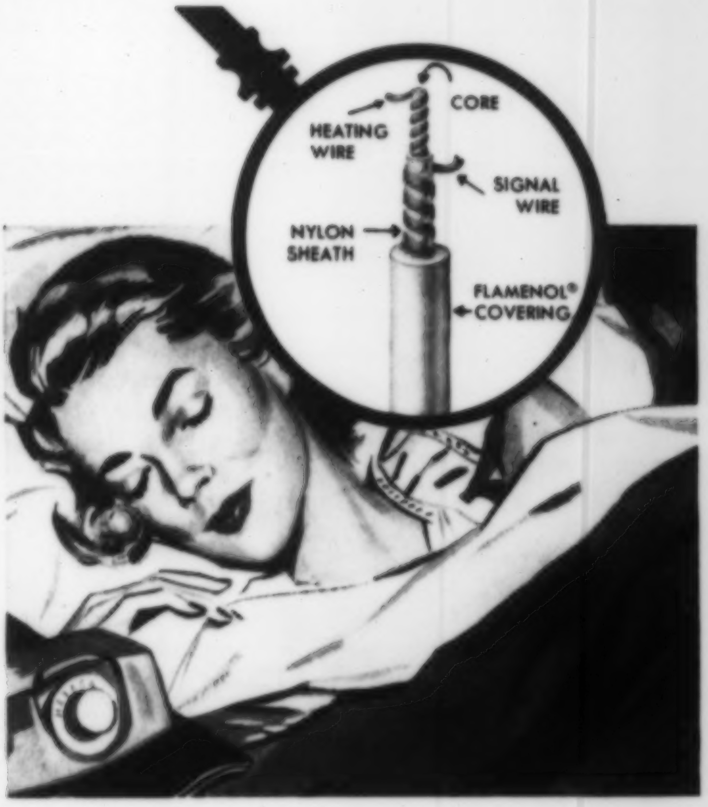
COMPACT COMPLEX PANEL shown here is hooked up to check out a guided missile's electrical system. Devised by Chance Vought Aircraft Inc., the panel contains 423 lights and 641 switch positions. Up to 90 cables tie it in to the missile to test the telemetering circuit, command control, starting and fuel system, landing gear and guidance systems

Women Engineers Could Solve Shortage

"Opportunities for women in the aircraft field are unlimited," Estelle W. Elliott, associate aircraft engineer at the Lockheed-Marietta factory, recently told a "women in aviation" banquet. "Although America has been battling an engineering shortage ever since

ANACONDA METALS AT WORK

A special alloy wire goes into the G-E SLEEP-GUARD Blanket . . . sheet brass into the Westinghouse Thermometer Set . . . and Everdur Copper-Silicon Alloys into the Sherwood Valve.



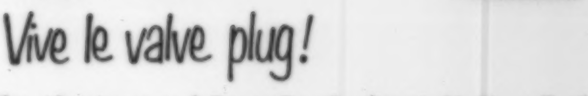
Shut-eye's safer with new shut-off control

Ahhh, sleep... it's wonderful! And now because of G. E.'s new SLEEP-GUARD Wiring System—made of two spiral wires separated by a nylon sheath—sleep's safer, too. If the heating wire becomes too warm, the nylon sheath—along with the heater and signal wire—automatically turns off your blanket. Both wires are made of Hitenso*, a cadmium bronze which provides just the right electrical and mechanical properties. We process almost 100 copper alloys into wire in a wide variety of sizes and shapes, tempers and finishes.

Betty Furness
THERMOMETER SET

A million at one clip for Betty

Anyone who's ever settled down before a TV set needs no introduction to charming Betty Furness of Westinghouse Studio One fame. Betty's currently offering her vast viewing audience this handy Westinghouse Kitchen Thermometer Set at a bargain price. And Westinghouse expects an overwhelming response. That's why they had Chaney Mfg. Co., Springfield, Ohio, make a million of these sets at one clip. And speaking of clips, those attached to these thermometers are made of coiled brass strip in the most economical alloy, gage and temper.



Vive le valve plug!

The Aluminum and Brass Co., Lockport, N. Y., calls this valve plug—which employs a nylon insert and operates under pressures up to 3,000 psi—the "heart" of their Sherwood Oxygen Valve. We're mighty proud about their enthusiasm, since the plug is made of one of our Copper-Silicon Alloys. Everdur*-1015 was chosen because roll-threading not only frees it from burrs but also work-hardens its surface, making it less likely to wear, gall or "freeze." Everdur-1015's cold-working properties also allow it to be rolled *over* the nylon insert. A tight "cap" results.

Want more information?

Our Technical Department's wide range of experience covers virtually the entire field of copper and copper-alloy applications in industry. If you have a problem of metal selection, we are at your service. *The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.*

*Reg. U. S. Pat. Off.

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the name to remember in

COPPER · BRASS · BRONZE

the start of World War II," she said, "almost nothing has been done to develop the largest single source of new engineering talent—women!"

She proposed that manufacturers begin a search for talented female college graduates immediately, commenting, "Industry is already scraping the bottom of the barrel to get male engineers, but the vast majority of college women have never been screened for engineering talent." She disclosed that only 3 of every 1000 women in industry are in engineering jobs—approximately 1500 for the entire nation.

Qualified women engineers, she said, can find jobs in aircraft research and development, design work, stress and aerodynamic engineering, mathematical analysis and related fields. The most critical year facing U. S. industry is 1955 when only 10,000 engineers will graduate to fill 30,000 new engineering jobs—only one-third of the engineers needed. Besides the severe current shortage, there is a past backlog of 40,000 unfilled jobs for experienced engineers.

"Electronic Supervisor" Controls Plant Facilities

A new "electronic supervisor" that follows preset programs and automatically controls up to 40 groups of remote operations—each on its own time schedule—has been demonstrated by International Business Machines Corp.

The new IBM Central Control System uses carrier-current signals and operates over existing electrical circuits. It does not require installation of transmission wires. The system will switch lights on or off, start and stop motors, open and close valves, control air conditioning and perform scores of similar operations. Its most advanced application will be to start and stop production-line machinery in automated plants.

Although the system will go through its operations automatically, manual operation is possible. A supervisor can break in on the control system at the central panel, or he can break in at any remote point.

Basic components of the system are its central operations panel, transmitter, and coded relays. The central operations panel is the source of the system's directions or "commands." Through its relays and an electronic transmitter, command pulses are sent to coded relays for operation of electrical services, with the coded relays rejecting all pulses other than those to which they are preset to respond. In the event that it becomes necessary to expand the system, it is designed so that additional circuits, pluggable relays and pluggable programming units may be installed at any time.

New Technique Molds Nonplasticized PVC

A new process for molding pure polyvinyl chloride has been announced by Stokes Molded Products Div. of the Electric Storage Battery Co. For the first time, according to Stokes, pure nonplasticized polyvinyl chloride (rigid PVC) can be processed in intricate and complex moldings.

Molding compounds of polyvinyl chloride usually incorporate fillers and plasticizers to facilitate processing. This technique reduces the plastic's natural chemical resistance and mechanical strength. Stokes claims their new process solves both problems and permits molding to close tolerances with

GAS-TURBINE COMPRESSOR used to start jet engines is being developed by Solar Aircraft Co. Unit shown here, a breadboard model under test, is a 500-hp gas turbine built into a mobile unit. Compressed air is bled from the turbine's compressor to a small turbine geared to the turbojet motor. This compressor is claimed to be lighter and more compact than an equivalent compressor driven by a piston-type engine and has the advantage of being able to use the same fuel as the jet engines being started

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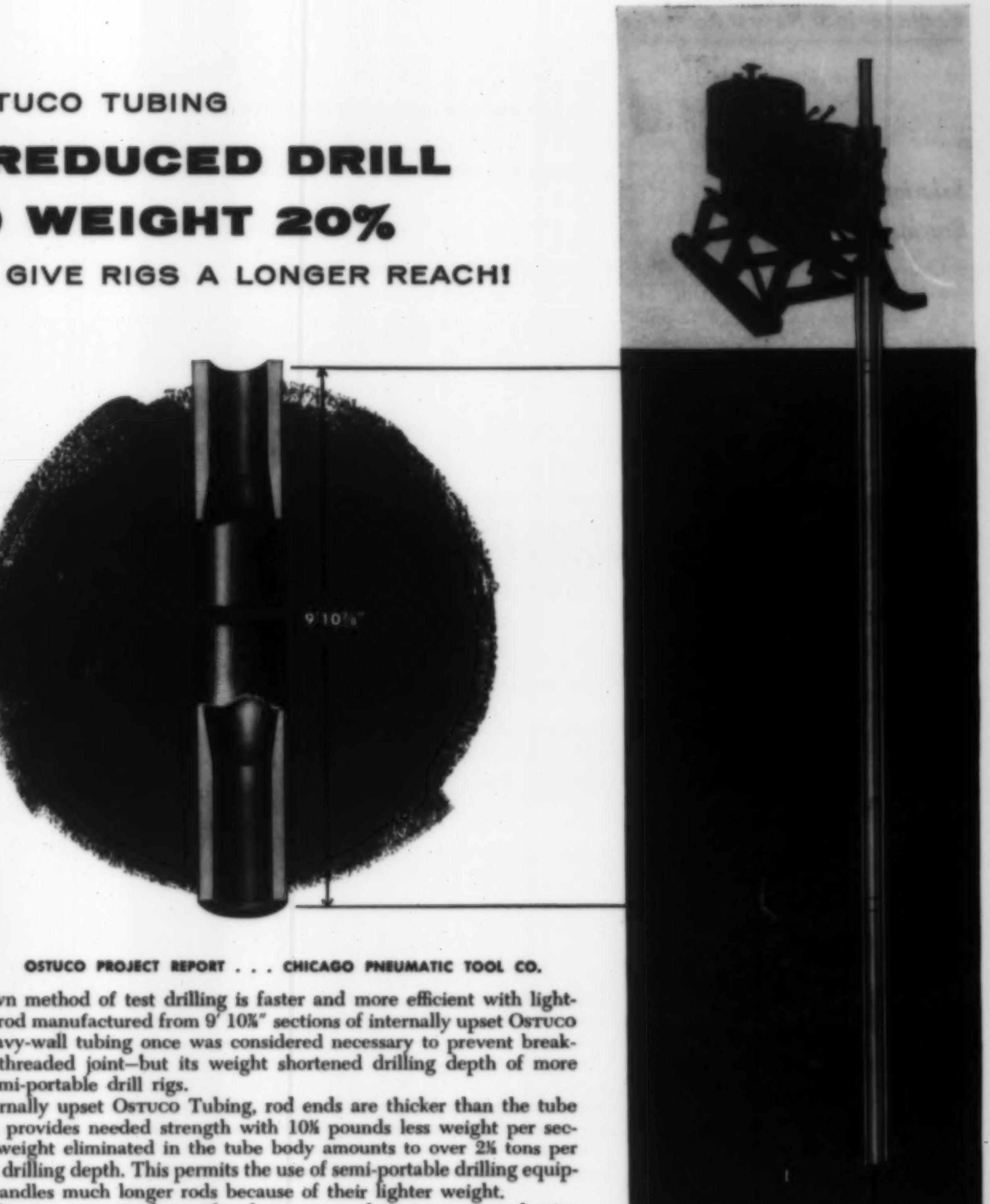
REDUCED DRILL ROD WEIGHT 20%

TO GIVE RIGS A LONGER REACH!



OSTUCO PROJECT REPORT . . . CHICAGO PNEUMATIC TOOL CO.

A well known method of test drilling is faster and more efficient with lightweight drill rod manufactured from 9' 10⅝" sections of internally upset Ostuco Tubing. Heavy-wall tubing once was considered necessary to prevent breakage at the threaded joint—but its weight shortened drilling depth of more practical, semi-portable drill rigs.

With internally upset Ostuco Tubing, rod ends are thicker than the tube body which provides needed strength with 10⅜ pounds less weight per section. Dead weight eliminated in the tube body amounts to over 2⅜ tons per 5000 feet of drilling depth. This permits the use of semi-portable drilling equipment that handles much longer rods because of their lighter weight.

This application may spark an idea for you . . . how to save production time and cost with versatile, *special-quality* Ostuco Tubing. And you'll be interested in Ostuco's unique *single-source service*, where one order takes care of all details. Write for catalog, "Ostuco Tubing," or send your blueprints for prompt quotation.

OSTUCO TUBING

SEAMLESS AND ELECTRIC WELDED STEEL TUBING
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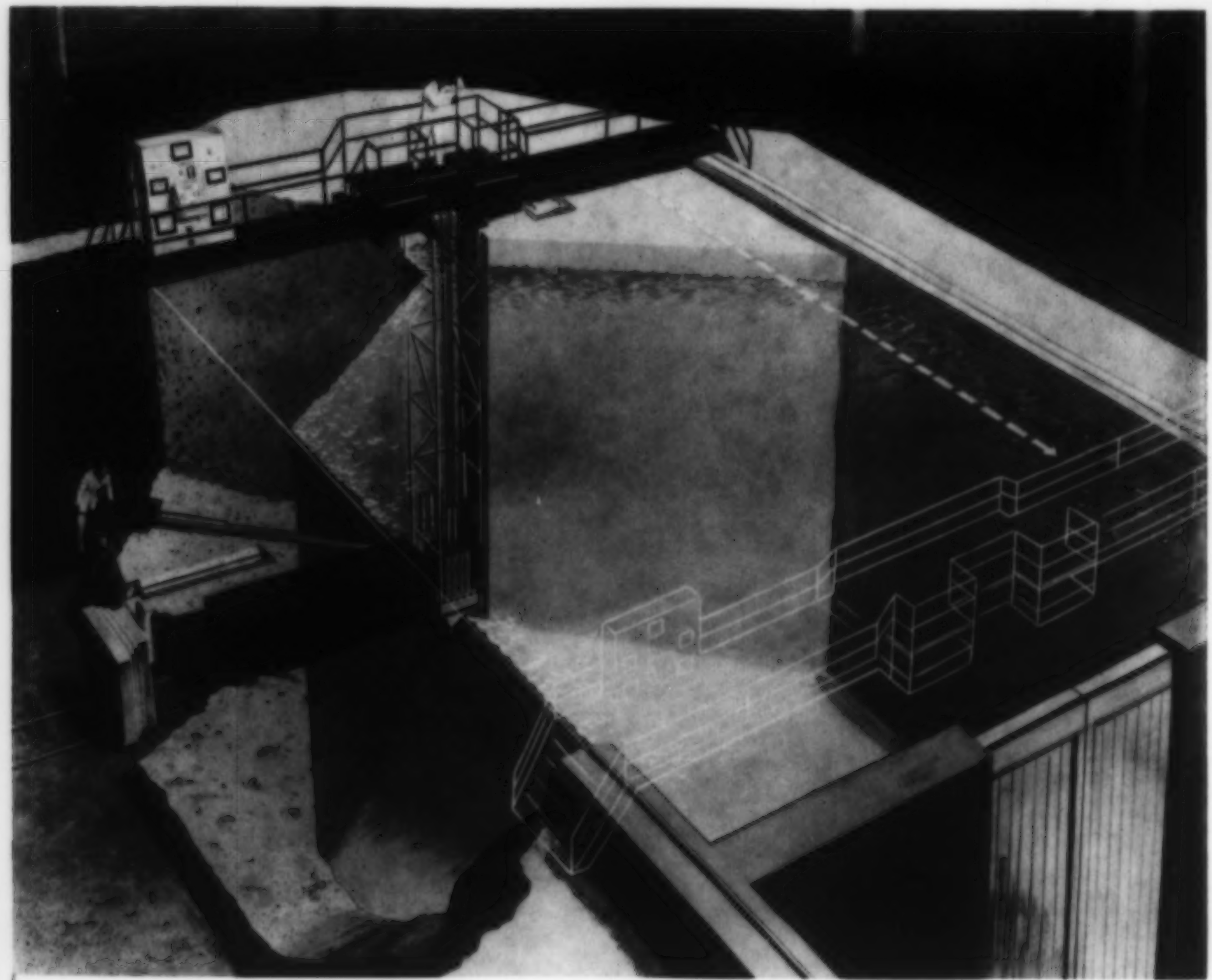
no more than minor finishing operations. Fully molded screw and bolt threads are said practicable.

Solution Offered For Brazing Sintered Parts

Sintered metal parts joined with low-temperature silver-brazing alloys can result in savings in material and labor costs over machining these parts from solid metal.

However, because of its occasionally high porosity, sintered metal may be tricky to braze. When the sinters are made dense, they can be brazed normally. But when the parts are porous—typically in bearing applications — porosity may interfere with the making of a good joint. Porous compacts tend to absorb the brazing alloy, much like a sponge soaks up water, leaving little or no alloy for the joint.

The technical laboratory of Handy & Harman reports a solution for overcoming pororosity problems when brazing sintered parts. The method consists of filling the pores just below the surface of the metal with colloidal graphite. By forming a nonwettable, nonabsorbent coating, the graphite prevents the alloy from soaking into the interior of the piece. Graphite emulsions, in either oil or water base, are available commercially for this purpose. In some cases the oil-base may be preferred because it usually penetrates into the metal more readily.



PRIVATE ATOMIC REACTOR: This cutaway drawing illustrates the first nuclear research reactor being planned by private industry. To be built by American Machine & Foundry Co., the reactor will be operated jointly by a number of industrial concerns. Cost of this "swimming pool" type reactor is expected to be in the neighborhood of $1.5 million. Its construction is to be based on a unitized design to insure flexibility for undertaking a wide variety of research and development work. Location of the proposed reactor will be in the New York area

From the collection of Paul J. Westergard, New Jersey Arms Collectors Club. Maker: Samuel Evans, Cambridge, England, 1800-1820. Prints of this illustration suitable for 11 by 14 frame available on request on company letterhead.

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Armed with the proper weapon you'll always be the winner in the unending duel of friction versus lubrication. There's never a misfire when you specify Bound Brook Oil-less Bearings, for Bound Brook offers you a bearing specifically designed for every application. *Where high shaft speeds and minimum friction are the prime requirements, COMPO Porous Bronze Bearings are consistent winners. Or, to combat shock loads as well as friction, it's hard to beat POWDIRON Sintered Iron Bearings for heavy-duty installations where tensile strength is the principal factor.* Both POWDIRON and COMPO bearings are available in sleeve, flange and self-aligning types in a wide range of alloys and sizes for every known application. Write or phone your nearest Bound Brook Man.

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LUXURY LINES: These four autos, according to their makers, have that something extra in the way of luxury and price. Buick's four-door hardtop, above left, is patterned after the Riviera two-door coupe. Center pillars between the doors have been eliminated to give it the lines of a four-door convertible. It is offered in the 236-hp Century and 188-hp Special series only. Wheelbase and overall length is the same as the four-door sedan.

Cadillac's Eldorado, above right, features a 270-hp V-8 engine and a modified Hydra-Matic transmission. Made only as a convertible, the Eldorado has dimensions that are the same as the rest of the Cadillac line. Only the engine and styling have been changed.

Packard's limited-production car, right, is the Caribbean. Powered by a V-8 engine rated at 270-hp, the Caribbean features Packard's new torsion-bar suspension system which replaces the conventional front-coil and rear leaf springs. Twin radio antennas projecting from the rear and three-tone color combinations give it a distinctive look.

Chrysler's "300," lower right, is now claimed to be the highest powered production car in the country. Rated at 300 hp, the engine is a modified Firepower V-8 with an 8.5 to 1 compression ratio. Modifications include two four-barrel carburetors, a full-race camshaft and rocker-arm valve adjustment. Stripped of all unnecessary trim, the "300" recently set a new national average speed record of 127.580 miles per hour

New Titanium Bolts Don't Tire Easily

First successful titanium bolts were recently fabricated for aircraft use. Fatigue life, formerly the major problem in the development of titanium parts, has been increased to the point of making the bolt useful for general aircraft use, it is claimed.

Pound for pound, the newly developed titanium bolts are said to be able to handle twice the load of an equivalent weight of steel bolts. According to Standard Pressed Steel Co., developers of the new bolt, solution of the titanium fatigue problem is expected to stimulate the use of titanium in the entire aircraft industry.

Compared to steel, titanium is a little more than half as heavy. However, titanium parts have been found to lose strength under vibration or other dynamic loads. Notch sensitivity is extremely high, another important factor to be considered in the design of bolts. Because of all these disadvantages, titanium has not found its way into critical stress applications. In aircraft design, its use has been limited to such things as landing-gear doors and engine housings.

New fabrication procedures have resulted in this new high-strength bolt which is said to make a part-for-part substitution of titanium for steel feasible for the first time. A weight savings of up to 1000 pounds may be possible for a single airplane.

Baker Brothers Inc. has announced the acquisition of certain of the assets of the Hall Automotive Equipment Line of the Waterbury Tool Div. of Vickers Inc. As a result, production of Hall valve-seat grinding machines and allied equipment has been transferred from Waterbury, Conn., to Toledo where it will be carried on under the name of Hall-Toledo.

New Techniques Shown At National Bureau of Standards

An atomic flame that may make possible new types of jet engines and a new device for speeding up high-speed computers were two of the "wonders of science" shown to visitors at the recent National Bureau of Standards Open House.

Two new radiation facilities, the Gamma Ray Laboratory and the Betatron Laboratory, were also shown to visitors for the first time.

In low-temperature research, the Bureau is developing methods for accurately measuring temperatures approaching −460 F. Low-temperature research provides new scientific techniques for understanding basic properties of materials and for using them to better advantage.

By studying the atomic flame, the Bureau hopes to obtain information that may eventually make possible new types of jet engines and rockets for operation at very high altitudes. A more immediate purpose is to learn more about burning under ordinary conditions so that industrial fuels may be used more efficiently.

The diamp (diode amplifier), a subsitute for the transistor, is a faster operating and a more economical device as applied in the computer field. The diamp makes possible a compact, rugged, high-frequency amplifier for use in pulse-type circuits and requires much less power to operate than conventional vacuum-tube systems. Important advantages of the diamp over the transistor are its higher operating rates, lower cost and commercial availability.

MODERN HERCULES: This Lockheed Hercules, otherwise known as the U. S. Air Force YC-130, has been designed for a number of difficult tasks, according to its makers. Powered by four Allison turboprop engines, the plane develops 15,000 hp. It is said capable of landing and taking off on short runways and will serve either as a cargo or troop transport. Wingspan is 132 ft.

Previews

More on Adjusting Speed

The big feature of this issue is Leo Spector's article on mechanical methods for speed adjustment on Page 168. The article will appear in two parts; the second installment will appear in June. In passing, we might mention that response to our first article in October on electrical methods for adjusting speed was terrific. Hope you like this one.

Jack of All Trades

As pointed out by Reuben Wolk on Page 154, a company's patent attorney can often provide valuable assistance to technical personnel. Patent attorneys are usually versatile fellows who not only know the legal aspects of a company's products, but also many of the technical facets of an engineering operation. Some of the ideas in the article are quite unusual: you might want to ask your own patent attorney about them—and you may be surprised to find that he can provide helpful talent in rather unusual areas.

Profitable Products

Designers are not usually called upon to sell the results of their efforts, but they must pay careful attention to all the sales-producing features of the designed product. One method of checking this factor —and of insuring that the product meets all the necessary functional and legal specifications—is a thorough evaluation procedure on any new or revised model. J. S. McChesney's article on Page 142 outlines just such a procedure, and one that might well be followed as a basic guide.

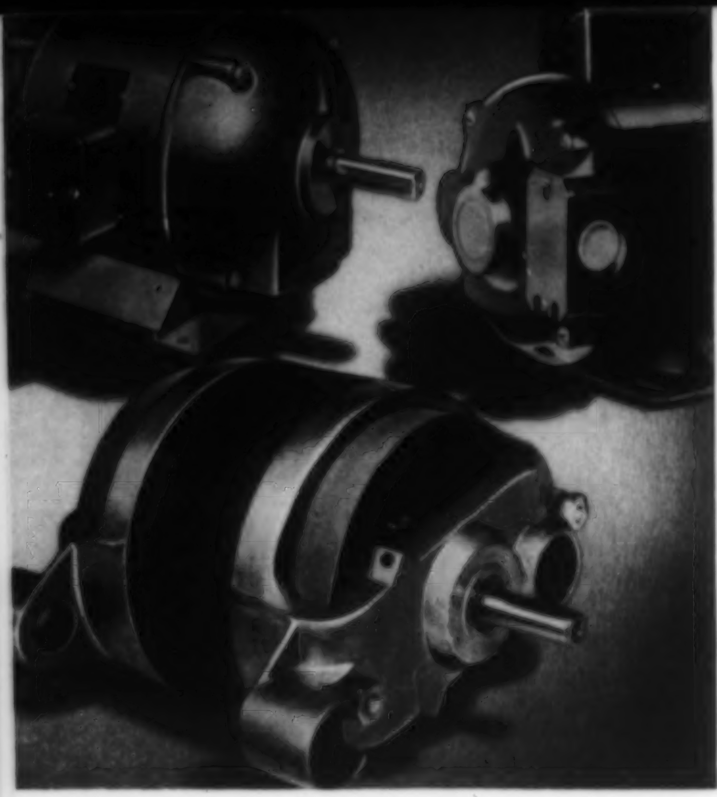
Facilities Stepped Up For Nickel Plating Process

New production facilities are expected to increase the use of chemical nickel plating. A new plant at Dunkirk, N. Y., said to have the largest capacity in the industry, was announced recently by the American Locomotive Co.

The process, called Alcoplate, is an adaptation of the Kanigen process, pioneered by General American Transportation Co. Chemical nickel plating is said to be capable of plating the most intricate surface with uniform thickness. It has zero porosity which assures freedom from corrosion of the base metals. Further, it is said to have excellent adhesion characteristics and applies an extremely hard coating of plate.

Among the advantages of the process are the increased service life of production equipment. Chemical nickel plating can be applied to inexpensive base metals. Components plated by the new method have been found to guard against contamination of processed materials.

(Continued on Page 24)



Complete Motors... or Motor Parts

Let your design problem make the choice!

Standard motors and matched motor parts represent only the beginning of what R & M is qualified to build! Special R & M fractional-horsepower with *any* housing design—or specially designed motor parts to fit your housings—are regular R & M contributions to products such as those listed at right:

Portable Saws
Drills
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Nibblers
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Vacuum Cleaners
Files
Sanders
Pumps
Compressors
Hones
Business Machines
Cast Cutters
Food Mixers
Polishers
Planers
Portable Grinders
Sirens
Hair Driers
Advertising Devices
Ventilating Equipment
Oil Burners
Surgical Instruments
Grease Guns
Vibrators
Die Sinkers
Waxers

The machine that tests motor performance . . . in minutes instead of months!

Formerly it took months to do a really thorough job of calculating motor performance and requirements for a given job. Now, using the unique R & M "Electrical Slide Rule," the performance of any one motor design can be calculated in about 20 minutes! Result? R & M can engineer a motor to your exact requirements . . . thoroughly, accurately, *and in time to meet your production and marketing schedules!*

You can expect quality . . . from every Robbins & Myers motor!

Here, for example, are some of the quality features built into R & M universal motor parts:

1. **Every field coil has paper in the slots—in addition to standard taping. More insulation means longer motor life, fewer failures.**
2. **Insulating material is selected for the job. For example, glass insulated wires are used in sander and saw motors.**
3. **R & M motors are varnish-dipped and baked—as much as *three times* when service requires it.**
4. **Standardized commutators and laminations—for mass-production at no sacrifice in quality.**
5. **Diamond-turned commutators . . . for greater concentricity and smoother surface finish. Brushes last longer!**
6. **Matched Motor Parts are precision-built, 100%-tested, dynamically balanced, fully interchangeable.**

How to select the best Fractional Horsepower Motors

FOR MACHINES, POWER TOOLS, APPLIANCES

The most important single factor in motor performance is *selection* of the right motor for the job. That's why R & M offers such a wide variety of types and sizes of motors and motor parts. From these many standard and special-standard types we can, in most cases, help you select the motor to help give your product the best all-around performance.

We Also Custom-Design, Economically!

Your problem may require a custom-designed motor. If so, we'd much rather work out a special motor for you than see you take an "off-the-shelf" compromise.

Ordinarily the extensive calculations required make custom-designing pretty expensive. We've licked that problem, too, with the unique R & M "Electrical Slide Rule." This is an electrical motor-performance calculator. With it, the designer can reduce the work of a whole day or two to about twenty minutes! Naturally you and we both benefit.

Some Other Advantages of R&M Motors

R & M offers some special construction features: extra insulation; glass insulation where heat requires it; diamond-turned commutators; extra varnish treatment; a gratifyingly low failure rate.

As a pioneer in the small motor field, we have designed and built millions of small motors for thousands of different applications. And so we naturally feel well qualified, with engineering skill and experience, and extensive manufacturing facilities, to do an exceptionally good job for you. At least, it won't cost you anything to find out.

Let Us Tell You More

Call the nearest branch office for an R & M Motor Specialist—or write us for the information in which you are interested. Use the check list below.

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Please send me, without obligation, information on:

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Fractional & Integral h.p. Motors & Generators
Electric Fans
Electric & Hand Hoists & Cranes
Moyno Pumps
Propellair Industrial Ventilating Equipment

(Continued from Page 21)

Carbide Plating Toughens Aluminum

High wear-resistance combined with light weight is said to be the result of coating aluminum with tungsten carbide by Flame-Plating. Developed by Linde Air Products Co., the process has been used for depositing a thin tungsten carbide coating on parts requiring extra wear resistance.

Extending the service life of a forged-aluminum drive arm was the problem of the Herman Nelson Div. of the American Filter Co. After trying other more expensive methods, designers plated the part with tungsten carbide. Wear life of the part was increased from 300 to 1000 hours.

Flame plating has been used for depositing thin coatings of tungsten carbides on surfaces or parts of tools where extra wear resistance is required. Its use on aluminum depends on the design of the aluminum part so that deflection under load is held to a minimum.

Plate magnesium, a new metals development of the Dow Chemical Co., will be featured at the forthcoming ASTE Western Industrial Exposition. Low-cost rolled magnesium plate is now commercially available in thicknesses from ¼ to 3 inches and in sizes up to 6 feet wide by 24 feet long. Industries expected to find uses for the new magnesium include aircraft, automotive, marine and boat, household appliances, agricultural equipment, railroad, bus, truck and trailer manufacturing.

AGMA Index for January, 1955 shows volume for the gearing industry to be decreased by 22.6 per cent as compared with December, 1954. The index figure for January, 1955 is computed to be 140.9. The AGMA index figures are computed using the 1947 to 1949 period as a base of 100.

Dream Truck Designed For All-Purpose Use

Another dream vehicle, this time a truck, has been designed for service as a delivery truck. With minor changes it can be converted into a taxi or station wagon.

Made by General Motors, the truck is called an all-purpose vehicle. Translated into French, it means "L'Universelle," the name given the vehicle.

Front-wheel drive permits the floor to be only 13 inches from the ground, or less than half the height of most trucks in use today. L'Universelle is 10 inches lower and 10 inches shorter than current model GMC panel delivery trucks. Wheelbase of this model is 107 inches.

A 180-hp V-8 engine is located behind and partly beneath the driver. Power is transmitted to the front wheels through an inverted Hydra-Matic transmission. A deDion drive permits the front wheels to move up and down independently of the frame.

Cooling of the engine is through an air intake in the roof. Ducts feed air down behind the driver to the tilted radiator core back of the driver's compartment. Maintenance is through access panels behind the seat and through the load wall.

Loading is through the rear door or two side doors. The side opening is 46 inches high by 48 inches wide and permits loading of bulky objects. When outfitted as a station wagon, the truck has a carrying capacity of nine persons.

General Motors "dream truck" features front-wheel drive and can be adapted to a number of uses. Wide loading doors, left, permit loading of bulky packages. A wrap-around windshield combined with no hood in front give the driver excellent visibility. Engine is mounted behind driver's compartment, right. A low floor level is maintained all the way to the rear

All these products are made better with Dylene* Polystyrene

- **REFRIGERATOR DOOR LINER** — Big moldings like this liner are easy to make when you use Dylene impact resistant polystyrene.
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- **INDOOR-OUTDOOR THERMOMETER**—It's easy to read the temperature through this transparent covering made with Dylene Polystyrene. This plastic is ideal for display packaging, too.
- **MEDICAL BLOOD SET**—High heat resistance, light weight and resistance to breakage made Dylene Polystyrene the right choice for this all-plastic blood and plasma infusion set.
- **RADIO CABINET**—Many appliance housings are made with Dylene Polystyrene because it is light weight, easy to clean, and has a smooth, attractive finish.
- **MODEL RAILROAD CARS**—Dylene Polystyrene can be molded into the most intricate shapes with fine engineering detail. Models and toys made with Dylene please kiddies because they look like the real thing.

A TREMENDOUS VARIETY of products can be made better with Dylene Polystyrene—tumblers and trays, children's trucks, planes and dolls, battery cases, air conditioner grilles, radio cabinets and television masks. All of these products are tough, durable and may come in all the colors of the rainbow.

Koppers makes a full line of different types of Dylene Polystyrene—each featuring a different combination of desirable properties. Your choice depends on the function of your product. Choose the right type of Dylene and you will get such qualities as high impact resistance, low water absorption, dimensional stability, high heat distortion.

Chances are Dylene Polystyrene can improve *your* product or reduce production costs. A Koppers engineer can give you technical assistance in selecting the proper Dylene polystyrene for your product. Write us today for more information.

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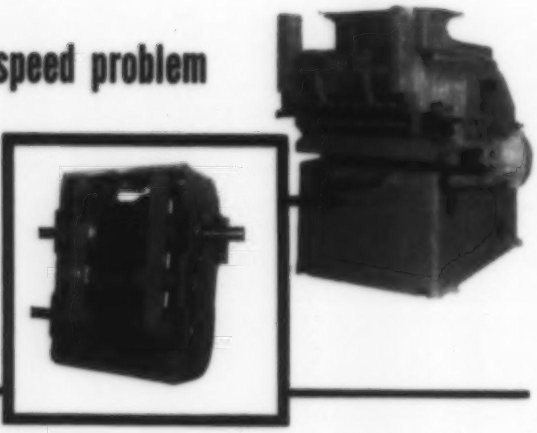

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News Roundup

Stacey Machine Works Inc., Agawam, Mass., has added a new department of machine design to their company. In charge of this new department is Mr. Robert E. Dow.

Carborundum Co. has established a new operating unit called the Electro Minerals Div. to manufacture and sell silicon carbide and fused alumina crudes, abrasive grain and related electric furnace products in the United States. In making the announcement, General Clinton F. Robinson, president of the firm, said that Joseph S. Imrie, formerly assistant to the President, will be general manager of the new division.

New Alloy Promises Hotter Gas Turbine Blades

Composed of relatively nonstrategic materials, a new nickel-base alloy has been developed to withstand high-temperature gas turbine and jet engine service.

Developed by General Motors Research Laboratories Div., the new alloy is called GMR-235. Besides nickel, GMR-235 consists of carbon, manganese, silicon, chromium, iron, molybdenum, aluminum, titanium and boron. According to GM, tests show that this new alloy is superior to many similar alloys containing higher percentages of strategic material.

Strength of GMR-235 is compared to some other commercial alloys in the accompanying table.

Stress-Rupture Data

Alloy	Stress* (psi)
S-816	24,000
H 536 (L 251)	29,000
H 531 (X 40)	28,400
Nimonic 90	28,000
Inconel X	28,000
Nimonic 80	24,000
GMR-235	34,000-41,000

*Stress to produce rupture in 100 hours at 1500 F

Stress-rupture and tensile tests were conducted at temperatures up to 1700 F. Tensile strength at that temperature was almost 50,000 psi. Yield strength was about 35,000 psi and elongation avraged a little over 20 per cent.

Work on heat treatment of the alloy has indicated that a solution treatment of one hour at 2100 F followed by air cooling can, in some cases, nearly double the stress-rupture life at 1600 F and 28,000 psi. Casting techniques and careful production methods are also important in the successful use of GMR-235.

According to General Motors, a test group of 114 engines have been equipped with buckets made of the new alloy. Of these, 56 have over 200 hours of engine service and 12 have accumulated over 500 hours. Average for the group is 183 hours with the maximum over 800 hours.

"I'd like you to handle this job, Johnston, since you seem to know all about worm gears."

Versatile Bottle Sealer Handles All Sizes, Shapes

Sealing a variety of bottles at high rates of speed is said possible with a battery of automatic machines now in operation at Hiram Walker & Sons Inc. At present, the machines apply plastic sealing bands on anything from a half-pint to a quart size bottle, either round or flat. Changeover time is only 5 minutes for changing bottle shapes and up to 30 minutes for extreme size changes.

Made by Gisholt Machine Co., the unit can be adjusted to seal from 50 to 150 bottles per minute. Seals are fed to the machine from magazine trays and

APEX universal joints

on the world's first multi-jet attack seaplane

Capable of speeds in excess of 600 mph, the XP6M-1 Martin Seamaster was built for the Navy as a mine-layer and photo-reconnaissance aircraft. The plane has a water-tight rotary mine door in the hull on which mine stores or a camera pod can be installed interchangeably.

NAVY
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APEX universal joints
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Advanced design and exclusive engineering features have helped earn acceptance for Apex **aircraft** universal joints. Precision craftsmanship and continued efforts to improve design and construction help maintain that acceptance.

Apex **industrial** universal joints embody these same service-proved features, incorporate the same engineering advancements. In a modern plant, with facilities and personnel devoted exclusively to the design and production of universal joints, you may find the answer to your most difficult design problems.

If those problems involve universal joints or universal joint assemblies, you should have our Catalog 27 and the helpful Engineering Data Sheets it contains. Please address your request on your company letterhead.

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Gentlemen:
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are self-aligning.

In sealing liquor bottles, Government tax stamps must not be covered. In order to assure perfect alignment between the seal and the stamp, an orienting unit was developed. Bottles are pushed around a semicircular path while spring-loaded arms force them against a guide rail. The resultant drag rotates each bottle until a lug on the bottle strikes an appropriate stop. If necessary, the bottle may rotate up to 360 degrees to become oriented.

After being positioned, the bottles are gripped at the bottom and held straight by arms at the top. Plastic seals are applied by eight-finger heads.

Although this machine was developed for use in the liquor industry, its designers say it can be adapted easily to the packaging of chemical, pharmaceutical and food products.

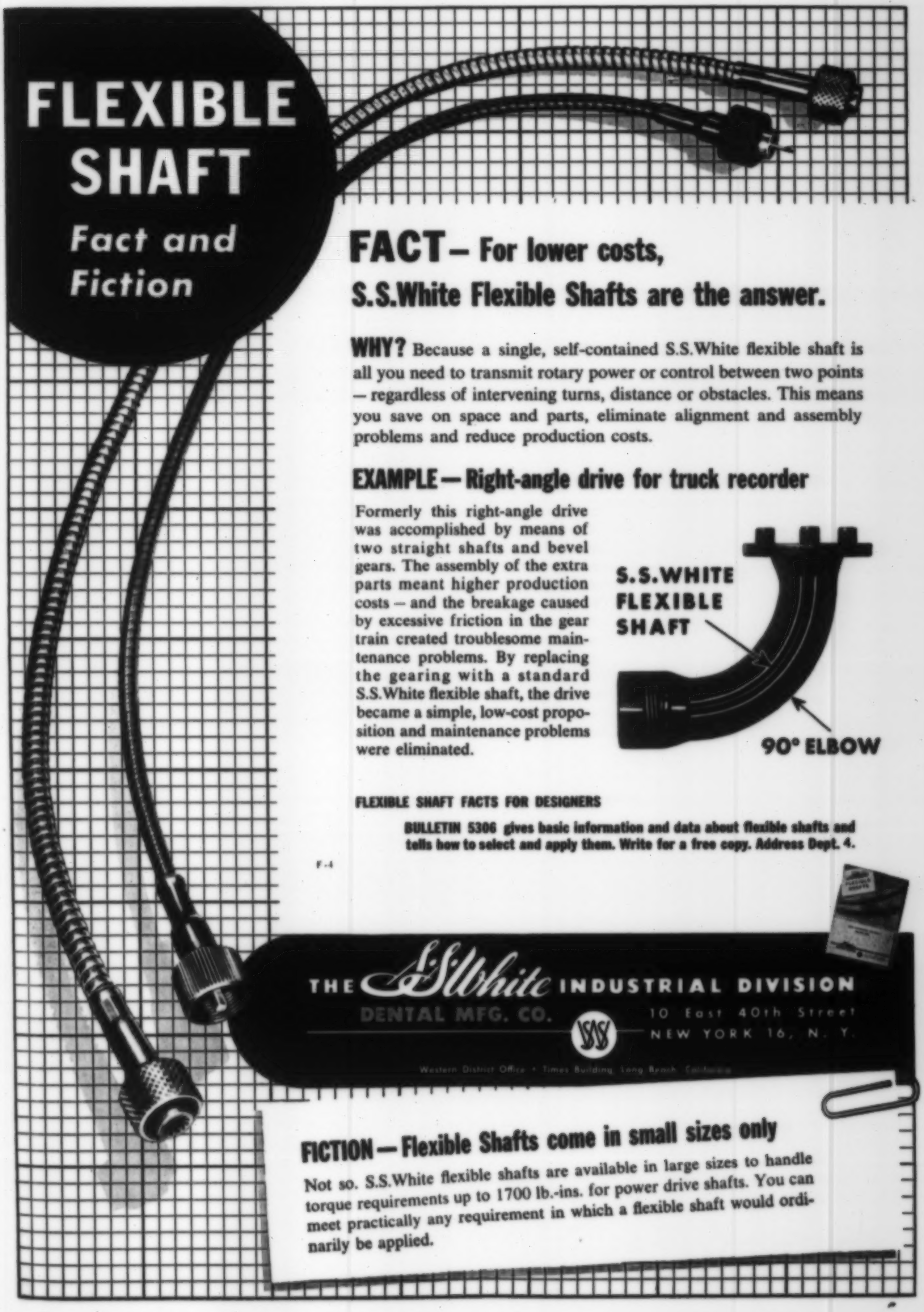
Bottles coming from the right move into this pocket wheel that spaces them for positioning in the sealing machine and rotates them so the tax stamp will be in alignment with a window in the sealing band. Positioning lugs can be seen near the bottom of the bottles

Look At Hot Spots With Water-Cooled Lenses

High-temperatures up to 3000 F are not usually conducive to good television camera operation. To permit remote viewing of high-temperature research operations, Radio Corporation of America has developed a water-cooled lens system.

According to RCA, camera lens temperatures may be maintained at less than 120 F where ambient temperatures are as high as 3000 F. Water is circulated through the system comprising a double glass lens, a reservoir, and a heat exchanger. In addition to water cooling, air is also blown against the lens and the camera for further cooling. An alarm system is provided in case of failure of either the air or water supply.

An engineering center to cost $5 million, will be built by Thompson Products Inc. on a site east of their plant in Euclid, Ohio. Individual buildings in the research center will be the Automotive Development Laboratory, Chemical Metallurgical Laboratory, Staff Industrial Engineering Laboratory, New Devices Laboratory and an Administration Building. The project, planned for completion by the



FLEXIBLE SHAFT

Fact and Fiction

FACT — For lower costs, S.S.White Flexible Shafts are the answer.

WHY? Because a single, self-contained S.S.White flexible shaft is all you need to transmit rotary power or control between two points — regardless of intervening turns, distance or obstacles. This means you save on space and parts, eliminate alignment and assembly problems and reduce production costs.

EXAMPLE — Right-angle drive for truck recorder

Formerly this right-angle drive was accomplished by means of two straight shafts and bevel gears. The assembly of the extra parts meant higher production costs — and the breakage caused by excessive friction in the gear train created troublesome maintenance problems. By replacing the gearing with a standard S.S.White flexible shaft, the drive became a simple, low-cost proposition and maintenance problems were eliminated.

FLEXIBLE SHAFT FACTS FOR DESIGNERS

BULLETIN 5306 gives basic information and data about flexible shafts and tells how to select and apply them. Write for a free copy. Address Dept. 4.

F-4

THE S.S.White INDUSTRIAL DIVISION
DENTAL MFG. CO.
10 East 40th Street
NEW YORK 16, N. Y.

Western District Office • Times Building, Long Beach, California

FICTION — Flexible Shafts come in small sizes only

Not so. S.S.White flexible shafts are available in large sizes to handle torque requirements up to 1700 lb.-ins. for power drive shafts. You can meet practically any requirement in which a flexible shaft would ordinarily be applied.

end of 1958, will resemble a "university type" development. Intended to facilitate the development of new products, processes and materials, the research center will enable the company to consolidate a number of its central staff engineering and research activities.

New quality-control laboratory is now in full operation at the Babcock & Wilcox Co.'s Tubular Products Div. plant at Beaver Falls, according to an announcement made by Edward A. Livingstone, vice president in charge of the division.

New Silicone Lubricant Is Tough At High Heat

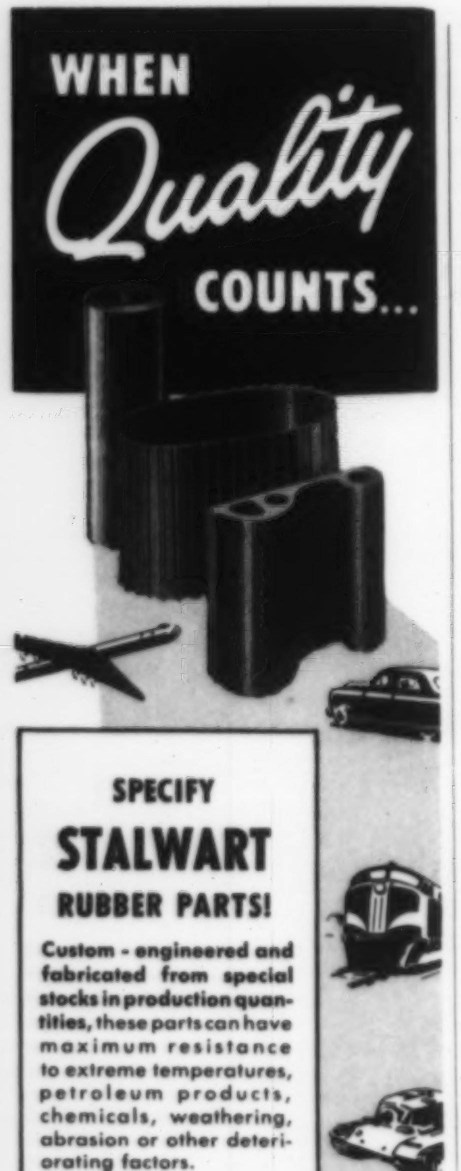
Better lubrication of high-temperature jet engine parts is claimed possible with a newly developed silicone lubricant. It has been found capable of operating at temperatures in excess of 400 F.

Both the new silicone fluid and new silicone greases are said to lubricate as effectively as hydrocarbons. Their thermal operating range is from −100 to over 400 F, and they show little change in viscosity or consistency at high temperatures. The new compound is said to resist shear breakdown.

Developed by General Electric, the new lubricant is said to combine the qualities of hydrocarbon with the properties of silicone. The compound has been developed for use in such industries as glass, steel, ceramics, petroleum and aircraft.

GE engineers claim that the lubricant is effective in steel-on-steel use and is applicable to most industrial purposes.

Honan-Crane Corporation, Lebanon, Ind., has changed their name to **Houdaille-Hershey of Indiana Inc.** Announcement of the change comes from the parent company, Houdaille-Hershey Corp. Formation of this corporation marks the first step in Houdaille-Hershey's plan to establish a filtration division and will strength-



WHEN *Quality* COUNTS...

SPECIFY
STALWART
RUBBER PARTS!

Custom - engineered and fabricated from special stocks in production quantities, these parts can have maximum resistance to extreme temperatures, petroleum products, chemicals, weathering, abrasion or other deteriorating factors.

STALWART will supply precision molded, extruded, die-cut or mandrel-built shapes to meet exacting original equipment requirements. **STALWART** parts will comply with individual, S.A.E. or A.S.T.M. specifications, and they can have varying degrees of hardness, tensile strength and elongation.

When QUALITY COUNTS . . . Specify STALWART!

Write today for **CATALOG 51SR-1** for complete information.

300-SR

STALWART RUBBER CO.

180 Northfield Road Bedford, Ohio

the only
Universal Joint
with the
"Telltale" Lock Ring
(patented)

TRADE MARK TO HALLMARK

Through the years, our trade mark has become a mark of quality that stands for the simplicity, efficiency and dependability of Curtis Universal Joints . . . the Hallmark of the industry.

In a wide range of applications, Curtis Joints offer the designer assurance of long life and trouble-free performance — because they are quality-controlled at each step of manufacture.

CURTIS UNIVERSAL JOINTS

- 14 sizes always in stock
- Fewer parts, simpler construction
- Complete equipment for government tests

Our catalog torque and load ratings are substantiated by constant tests. You can depend on them.

Not sold through distributors. Write direct for free engineering data and price list.

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As near to you as your telephone

A MANUFACTURER OF
UNIVERSAL JOINTS SINCE 1919

en research, engineering and production facilities.

Aerophysics Development Corp., Los Angeles, has been acquired as a wholly owned subsidiary by Studebaker-Packard Corp. According to James J. Nance, president, the purchase is a first move in Studebaker-Packard's intention to seek a larger share of defense business. Headed by its founder, Dr. William Bollay, the new subsidiary has a staff of 200 engineers and scientists.

North & Judd Manufacturing Co., New Britain, Conn., has purchased the physical assets, inventories and patents of the E. A. Bessom Corp., Salem, Mass., it was announced by Frederick L. Morrow, president of North & Judd. The Bessom Corp. has been manufacturing sheet metal self-locking nuts under the name Con-Torq Nuts and Wing Nuts.

Miniature Chamber Tests At Ultra Low Temperatures

Tensile tests on metals at temperatures as low as −452 F are being conducted by metallurgists at Westinghouse Research Laboratories. The metal specimens are stressed within a specially designed chamber which has been cooled with liquid helium. Results of these tests will provide engineers with information on the types of metals best suited for use under extreme temperature ranges.

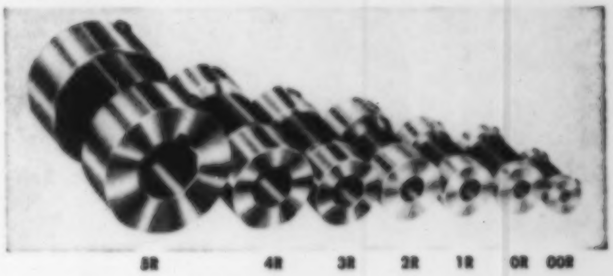
Although much larger testing apparatus has been used in low-temperature experiments in the past, the Westinghouse-developed chamber, only slightly larger than a hand fire extinguisher, is believed to be the first of its kind to attain the −452 F mark for purposes of tension testing. Prior to use of liquid helium as refrigerant, tests were conducted at temperatures as low as −320 F using liquid nitrogen.

The new testing temperature of −450 F is just short of absolute

(*Continued on Page 36*)

"must flexibly deflect to 20° under 50 in. lbs."

specify Guardian FLEXIBLE COUPLINGS



Freedom of the designer to select and specify the exact length which his drive requires—*plus* very low outside diameter of coupling for the load it carries—*plus* the availability of Flex-Elements to meet special drive problems like the example given here—*plus* one-piece construction in 1/15 to 3 HP series—these are reasons for more and more OEM specifications of Guardian DYNA-LINE flexible couplings.

Our Product Application Department will welcome consideration of your coupling problem. GUARDIAN—also producers of the molded nylon splined sleeve coupling.

Write for Catalog Page C-102 and Drive Data Form #53.

FROM OUR PRODUCT APPLICATION FILE
Case History No. 25-3-R

Problem: A deposit drawer for drive-in banking activates a limit switch just before reaching the extreme limit of its travel. The momentum built up by the gearhead motor imposes approximately 50 in. lbs. upon the arrested motion of the drive train. To protect the gears against this sudden shock a flexible coupling is required which will deflect flexibly 20° in rotation under this load.

Solution: A study of the load deflection involved, with the normal running torque in this drive, found its answer in one of the several Flex-Elements available in Dyno-Line couplings. The No. 3-R in 4¼ inch length was then selected. No premium price for so-called "non-standard length".

Guardian PRODUCTS CORP.
COUPLING DIVISION
Dept. IC-M, 1215 E. Second St.
Michigan City, Indiana

Guardian
QUALITY IS TRUE ECONOMY

GENERATED HELICAL ROD

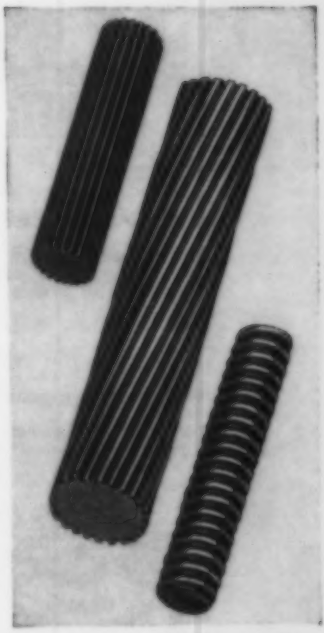
Mass Gear can generate spur, helical and worm pinion rod in all types of material including plastic.

Mass Gear can also produce any type of serrated or special form rod that can be generated.

These rods are available up to 6 feet in length, from 5/32" to 1¼" in diameter.

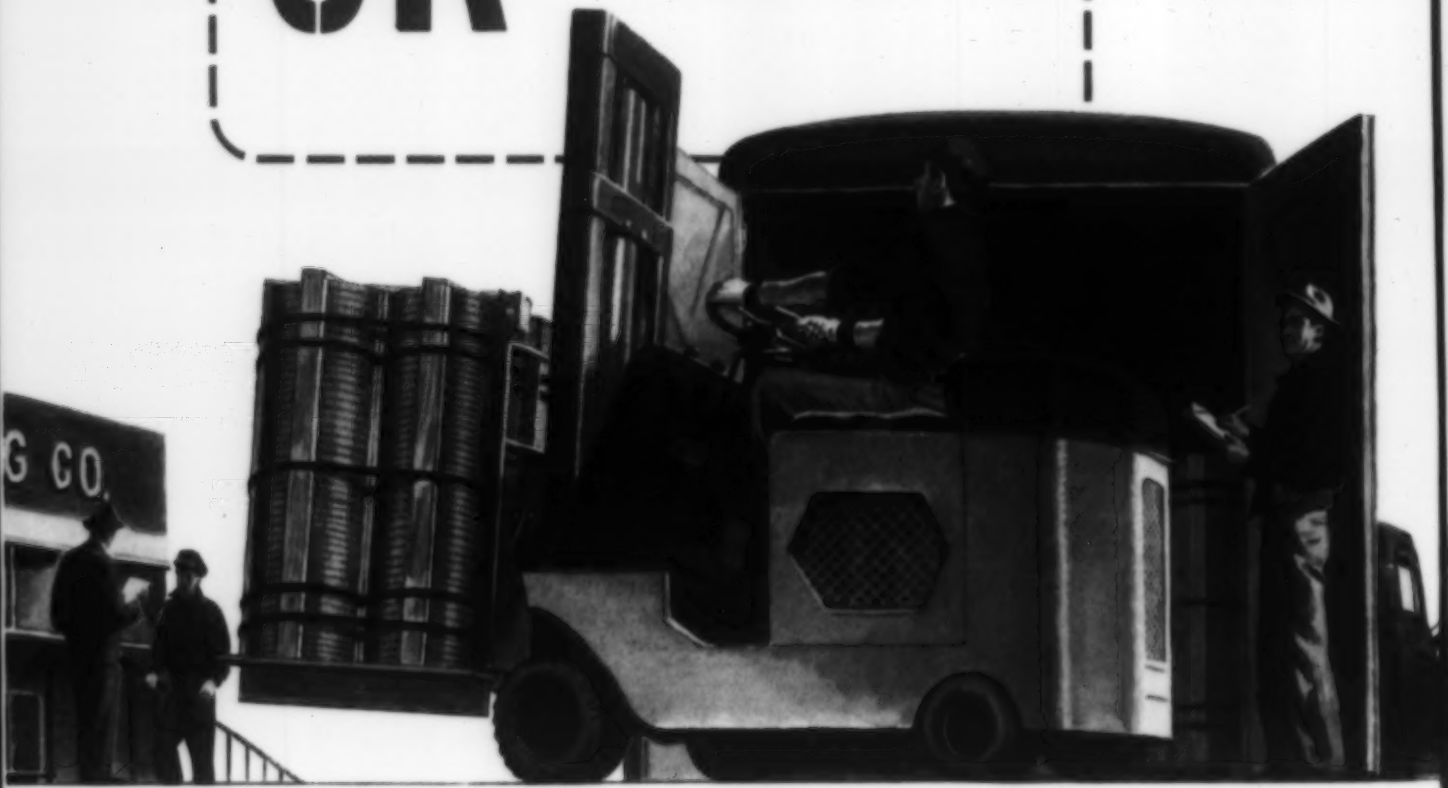
Mass Gear products are made to A.G.M.A. standards, thus insuring uniform quality.

Illustrated brochure showing interesting designs and suggestions available upon request.



Massachusetts Gear & Tool Co.
WOBURN, MASS.

OK and ON TIME



...from YOUR GEAR DEPARTMENT

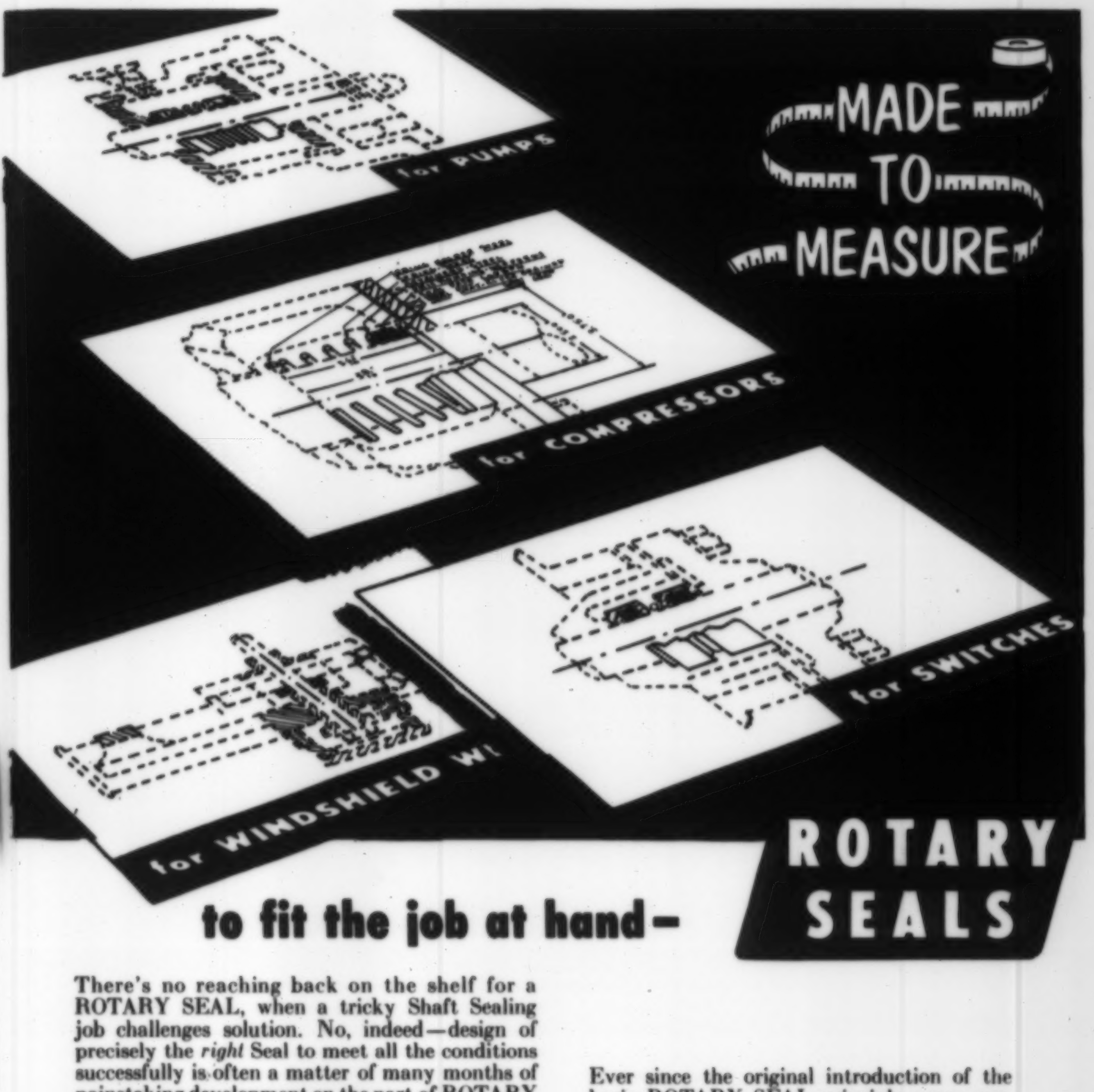
Using our facilities as *your gear department* puts our entire organization on your team with production-line precision. Gears—constantly to your specifications—arrive on schedule, and you are relieved of the responsibilities of building and maintaining a gear department equal to your requirements in *know-how* and production facilities. Most of our customers use us in this manner—employing our experience in the solution of gear problems—placing confidence in a company whose sole business is gears, and whose business has been built on living up to both specifications and expectations. May we discuss such a mutually advantageous arrangement with you?

DOUBLE DIAMOND TRADE MARK GEARS

FOR AUTOMOTIVE, FARM EQUIPMENT AND GENERAL INDUSTRIAL APPLICATION
GEAR-MAKERS TO LEADING MANUFACTURERS

Automotive Gear Works, inc.

ESTABLISHED IN 1914
RICHMOND, INDIANA



ROTARY SEALS

to fit the job at hand–

There's no reaching back on the shelf for a ROTARY SEAL, when a tricky Shaft Sealing job challenges solution. No, indeed—design of precisely the *right* Seal to meet all the conditions successfully is often a matter of many months of painstaking development on the part of ROTARY SEAL's specialists in Seal engineering. We tell manufacturers of original equipment, "Call us in at the drawing board stage, if possible—we can often come up with suggestions which will cut both original costs and repair worries."

Ever since the original introduction of the basic ROTARY SEAL principle years ago, more and more leading manufacturers in every field have turned here for the one *right* answer to Shaft Sealing difficulties where production volume is involved. We've helped them solve many an "unsolvable" problem by painstaking engineering and a practical approach. There's a wealth of experience behind every ROTARY SEAL application design!

THE ROTARY SEAL COMPANY

mechanical seals for rotating shafts

Shaft-Sealing with Certainty

2022 NORTH LARRABEE STREET
CHICAGO 14, ILLINOIS, U.S.A.

here's another NORDBERG POWER CHIEF DIESEL UNIT

designed and built for a specific powering job . . .

THIS two-cylinder Diesel generating unit was designed and built by Nordberg to meet a special mechanical refrigeration power need. Utilizing a "standard" Nordberg POWER CHIEF Diesel engine, this power unit points up the fact that you can get "stock" engine economy in an "engineered power package" by letting Nordberg engineering facilities help in providing a *perfect match of power and machinery.*

In the range of 10 to 45 horsepower, or 6 to 30 kilowatts, Nordberg *POWER CHIEF* Diesels can be furnished with the type of drive, generator or special equipment you need to meet your specific power needs.

Mail the coupon for full details.

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Builders of America's Largest Line of Heavy Duty Diesels

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Please send full details on Nordberg POWER CHIEF
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MD

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4-255-OEM

(*Continued from Page* 31)

zero or −459.6 F. Aims of these low subzero investigations are a better understanding of the strength of metals and the factors that cause embrittlement failures.

In actual testing, liquid nitrogen is used for initial cooling of the chamber from room temperature to −320 F. At this point liquid helium is introduced to take the temperature down to −452.

Nitrogen is used in the room temperature to −320-degree range because it is considerably more economical and efficient than is the use of helium at these temperatures. Using these two refrigerants, tests can be conducted at any temperature from zero to −432 F.

• • • ROUGH ROCKETS *will be a thing of the past when results of studies of rocket vibrations are put into practice. Researchers at Stanford Research Institute have been concerned with pressure oscillations inside the rocket motor. These disturbances have been known to throw the projectile off course or even destroy it. Acoustic qualities of various liners seem to be the key to controlling these unwanted vibrations. If all goes well, that 238,857-mile trip to the moon should be quite smooth.*

Plastic Samples Cast From Plastic Molds

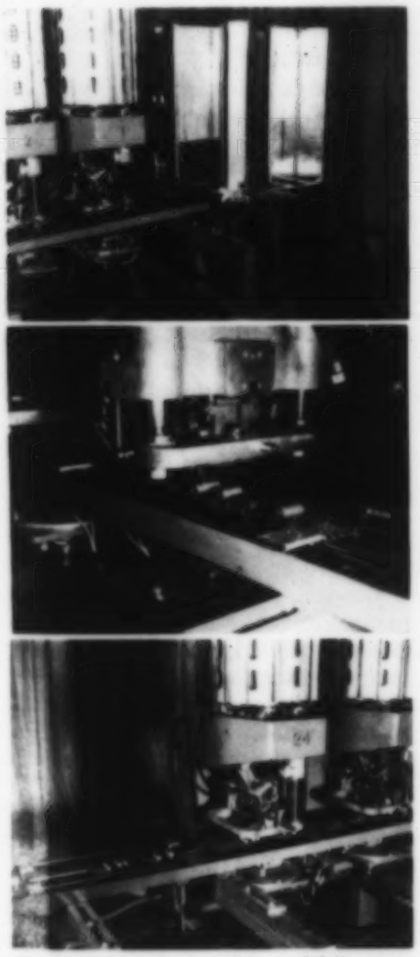
Sample plastic parts can be made inexpensively by using plastic molds and a modified injection molding technique. Developed by Applied Engineering Associates, the technique enables finished parts to be made using inexpensive or expendable molds.

For samples or small production runs, multicavity plastic molds of plastisols, polyethylenes, etc., are prepared. The mold is subjected to vacuum, and liquid resin mix is injected. After curing, the parts are released and the mold filled again.

Although not a high-speed production process, the technique is particularly adaptable to short production runs because of its low cost. Availability of an inexpensive finished plastic sample is expected to enable the product designer to better determine the utility of the final product.

Automatic Machine Assembles Electronic Circuits

An automatic assembly machine for attaching a variety of electronic components to printed circuit boards has recently been developed. Called "Autofab," the machine was designed and built by the Mechanical Div. of General Mills Inc. for IBM.



Beginning of the "Autofab" automatic assembly line, top, shows the printed circuit cards fed from the turret down onto the conveyor. A small resistor, middle photo, is being placed on the board by one of the attaching heads. Completed assemblies, bottom, roll off the end of the line

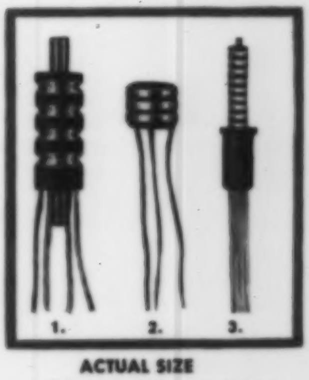
Printed-circuit assemblies for air-

When size is important...

MISS AMERI
CONTEST

FOR SLIP RING ASSEMBLIES NO BIGGER THAN THIS **CALL P M I.**

Slip ring assemblies we have made measure no more than .080" diameter by .450 inches. We can make them smaller or larger, with more or fewer circuits. Many of our miniature slip ring assemblies are carried in stock and can save you development and die costs. Ask for booklet, "Miniature Slip Ring Assemblies."



ACTUAL SIZE

1. Coin silver rings molded in melamine.
2. Gold rings molded in nylon.
3. Plated rings in cast resin.

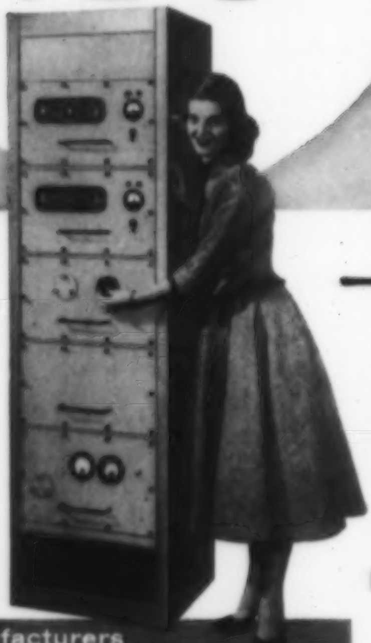
PMI

P M INDUSTRIES, INC.
264 Fairfield Ave.
Stamford, Conn.

Attention: Executive in charge of getting the **JOB DONE!**

Magnetic Amplifiers · INC

AFFILIATE OF
GENERAL CERAMICS
CORPORATION



—solicits your inquiry to AUTOMATIZE SPECIFIC PRODUCTION PROCESSES IN YOUR PLANT

Manufacturers of Tubeless:

Mobile Power Supply Regulators
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Transi-Mag* Amplifiers
Analog Computers
Photoelectric Controls
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*TRANSISTOR MAGNETIC AMPLIFIERS, TRADEMARK

For Application on Commercial and Military:

Aircraft **Machine Tools**
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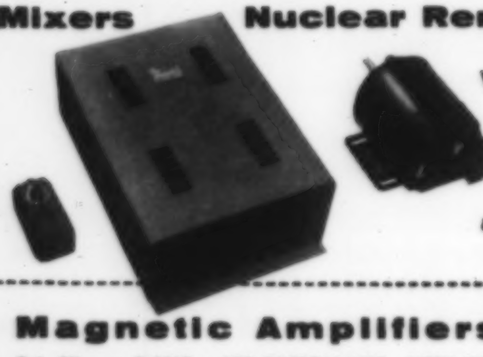


We custom design, manufacture and install controls and control panels.

Magnetic Amplifiers • Inc
Tel. CYpress 2-6610 • 632 TINTON AVE., NEW YORK 55, N. Y.

defense computers are expected to be turned out at the rate of about 200,000 a month. Only three people, two operators and a supervisor, are necessary to operate the machine, according to the designers.

Up to 24 components may be attached to the boards at one pass down the automatic assembly line. Attaching heads are controlled by a camshaft. As each printed circuit reaches a position under the attaching head, the conveyor stops momentarily. The head then attaches its component, and the conveyor then moves the board to the next position.

After completing a full cycle, the assemblies are ready for dip soldering. General Mills is building an IBM-designed machine to do this operation.

This completed printed circuit board was automatically assembled by the "Autofab"

Loading of unpolarized components into the "Autofab" is merely a matter of pouring them into a hopper. Polarized components are fed into the machine from preloaded magazines. Magazines are turned automatically so that when one is emptied, a full one moves into position. Suitable signalling devices are incorporated into the machine to warn the operators of a nearly empty hopper or magazine. Should a head exhaust its component supply, the machine stops so that no material will be lost through defective assembly.

Many varieties of printed circuit plates may be accommodated. Size of the boards may vary from 2 to 10 inches in either dimension. Attaching heads are interchangeable and may be positioned at any station in the line. According to General Mills, minor design changes could be made to adapt the present machine to even greater varieties of board sizes and configurations.

While the present machine is being used to turn out components for Air Force computers, it is said adaptable to a variety of industrial uses. General Mills engineers say that it is possible to develop a machine that not only does all that "Autofab" is doing, but will also insert conventional electron tubes into the plates.

In the planning stage also are machines to test and encase the entire assembly in a moistureproof coating. A preparation machine is being built to prepare and automatically load components into the assembly machine.

Lots of Air Gives Battery Long Life

Sintered plates which are 80 per cent porous are responsible for greater current capacity and long life of the nickel-cadmium battery. The plates are composed of carbonyl nickel powder with nickel wire screens to hold the powder in place.

Made by Amplex Div. of Chrysler Corp., the battery has an extremely low discharge rate. It is said to have the ability to operate in temperatures from −65 to 165 F. The battery can be 50 per cent charged in 15 minutes and fully charged in 1 hour.

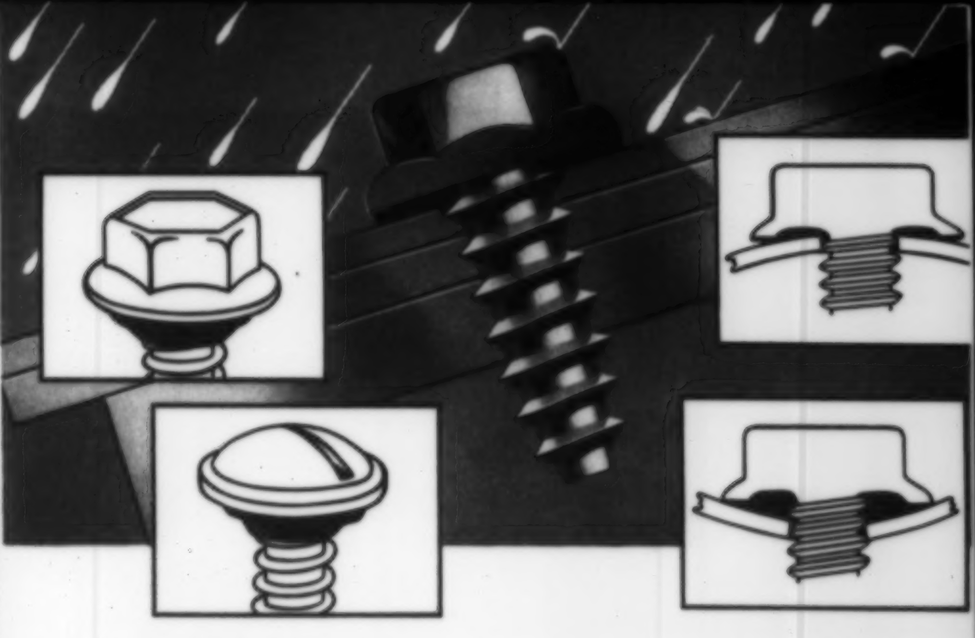
Design Show Is Postponed

According to a recent announcement, the former Basic Materials Show, now called the Design Engineering Show, has been postponed for a year.

Originally scheduled for May of this year, the show is now planned for late Spring of 1956. According to Clapp and Poliak Inc., managers of the show, not enough time was available to arrange for the necessary changes to incorporate the design engineering concept into the exposition.

Along with the exposition will be a Design Engineering Conference which, the managers say, will en-

(*Continued on Page* 42)



New *Tuff-Tite* * Fastener Prevents Leaks—Protects Surface—Absorbs Shock—Stops Squeaks

Tuff-Tite is a new multi-purpose fastener with a one-piece metal head and assembled neoprene washer that gives you quick, secure, economical, leakproof fastening of metals and plastics.

Use of Townsend's Tuff-Tite makes possible watertight fastening of galvanized steel, protected metal, stainless steel, aluminum, plastic and other roofing and siding materials at substantial savings over conventional fasteners.

Leaks between the head of the screw and the metal washer are impossible because they are made as one piece. When this fastener is tightened, the pre-assembled neoprene washer is trapped and controlled by an undercut in the washer head. The neoprene is forced into the hole and around the threads to form a watertight and airtight seal.

Tuff-Tite fasteners provide surface protection in assembly of appliances and similar products. The neoprene washer provides a cushion that permits tight seating without cracking or chipping porcelain enamel and other fine finishes.

Where vibration noise is a problem in automobiles, railroad passenger cars and machinery, the cast neoprene washer on Tuff-Tite fasteners acts as a shock absorber—eliminates squeaks and chatter.

Tuff-Tite fasteners are available as self-tapping screws, thread cutting screws, drive screws, machine screws, stove bolts, wood screws, nails and special products. They are made of carbon, alloy and stainless steel, aluminum, copper and other metals in a variety of head styles.

To learn more about how Tuff-Tite can increase your fastening efficiency—improve your products, use the coupon below or write.

**Trademark*

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NEW BRIGHTON, PENNSYLVANIA
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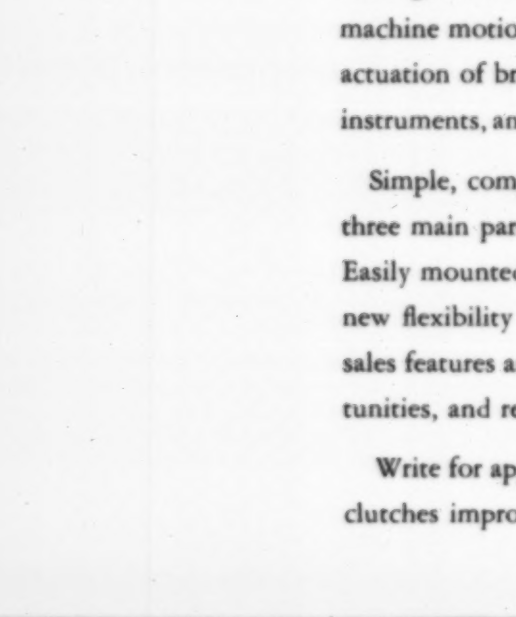
FASTER MORE PRECISE

WARNER *ELECTRIC* MOTION CONTROL . . . newest and fastest method for starting and stopping rotary drives . . . *first* truly accurate means of positioning, indexing, inching and jogging, interlocking, and synchronizing machine motions . . . *only completely electric* control for remote or automatic actuation of brakes and clutches . . . *now* ready for use on small machines, instruments, and servo drives having torque requirements up to 240 inch lbs.!

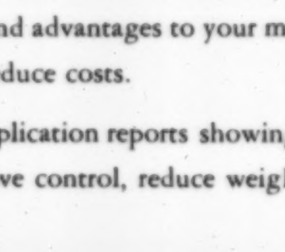
Simple, compact design (largest size only 4¼ inches in dia.), with only three main parts . . . virtually no mechanical movement during operation. Easily mounted with bearing- or flange-mounted field. Give you complete new flexibility in selection and use of automatic controls. Add powerful sales features and advantages to your machines, expand automation opportunities, and reduce costs.

Write for application reports showing how these new *electric* brakes and clutches improve control, reduce weight requirements, and cut costs!



NEW CONTROL UNIT CUTS EQUIPMENT COSTS...

Warner's *new* Model CW 600 Control is a simple "plug-in" unit for converting a-c to d-c required to power 90 volt SF and RF 160, 250, and 400 Electric Brakes and Clutches. Both clutch and brake may be powered from the same control. Or, if a single brake or clutch is used, the circuit over-excites the field, speeding actuation. It's easy to install and service. Now in production and ready for delivery at a real money-saving low price!



Electric Clutch-Coupling

Only 6 to 15 watts of direct current are required to energize the clutch (or brake) field. Flux path is through the rotor and armature . . . the field is stationary. Design simplifies installation. Wear is between armature and friction facing on rotor—there's *no wear* on field. Armature is completely self-adjusting.

POWER TRANSMISSION CONTROL FOR LIGHT MACHINES AND INSTRUMENTS

Put powerful new sales appeal in your machines

High torque easily controlled—smooth and surprisingly high operating torque . . . positive engagement for heavy loads . . . no creep or slippage . . . voltage easily adjusted to give you *cushioned* or *abrupt* couples or stops.

Compact, lightweight—ideal for small electrically operated instruments and machinery . . . applications before limited because of space restrictions or high-torque needs.

Precise, accurate positioning—lightning-fast operation . . . cycles easily adjusted for any requirements.

Easy remote or automatic control . . . electro-magnetic principle permits automatic operation and remote control through limit switches, relays, electric eyes, and other standard electric controls.

Never need adjustment—automatic take-up for wear of friction surfaces eliminates servicing . . . replaceable face and rotor extend brake or clutch life indefinitely.

Simple design—only three operating parts—magnet, armature and replaceable face, or rotor. Nothing to go wrong . . . easily wired into standard machine circuits using light-duty components.

WARNER

Beat competition with

ELECTRIC BRAKES AND CLUTCHES

Warner Electric Brake & Clutch Co., Beloit, Wisconsin

Warner Electric Brake & Clutch Co.
Dept. MD, Beloit, Wisconsin

Gentlemen: Please send literature describing "SF" Electric Clutches and "RF" Electric Brakes to:

Firm Name________________________

Individual________________________

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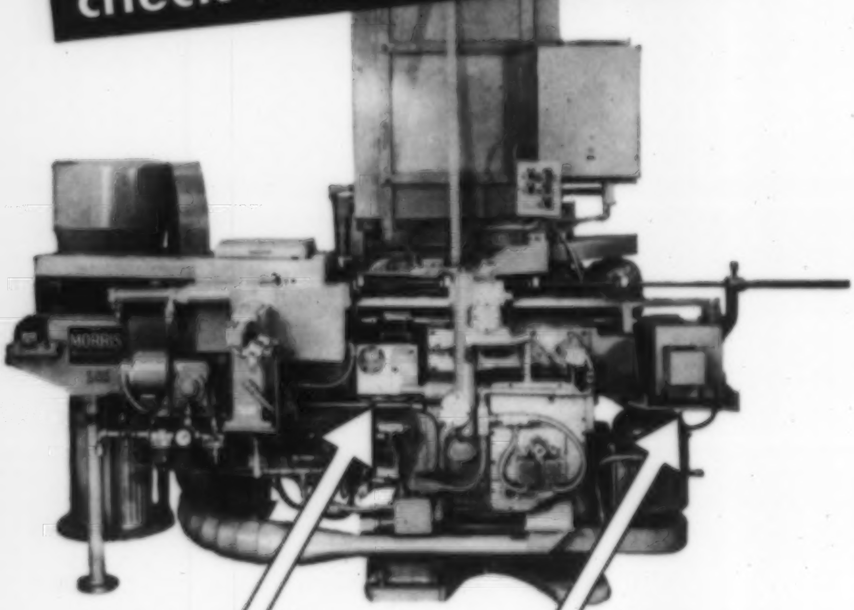
City______________ State__________

Built-in SCALES pre-set machine and check finished product



PRE-SET BY EXACT WEIGHT

In MORRIS PISTON MILLING MACHINE, scale No. 1 determines amount of overweight that must be removed to balance pistons. Linkage transfers reading to depth of cut and sets machine for milling off the correct amount of excess pad.

INSPECTED BY EXACT WEIGHT

After milling, piston travels to the second scale where it is checked against predetermined weight. The SHADOGRAPH scale is adjusted to one gram, plus or minus. Should final check show over or under this amount, machine is automatically stopped.

The above application shows how EXACT WEIGHT precision designed scales can be fitted into modern machine tooling to bring your operations a step nearer automation.

If you are now designing machines or products that require accurately controlled weight as a part of their manufacture, investigate our SHADOGRAPH Scale application. These scales can be easily built into most modern production machines. Their absolute accuracy adapts itself to complete electronic application and control.

Complete engineering data is available for designers. Write, giving your specific application.

Sales and Service Coast to Coast

There is no substitute for Exact Weight

Exact Weight Scales
Better quality control
Better cost control
THE EXACT WEIGHT SCALE COMPANY
923 W. Fifth Avenue, Columbus 8, Ohio
In Canada: P.O. Box 179, Station S, Toronto 18, Ont.

News Roundup

(*Continued from page* 39)

compass all aspects of design engineering. Purpose of the new show and conference, according to Clapp and Poliak, is to provide a new source of information for design engineers.

THINK
THINK
THINK

"Boss, I've been thinking . . ."

Stronger Plastics Made from Corn Cobs

Corn cobs and other vegetable by-products can be used to make stronger plastic laminates, according to the Wright Air Development Center. Research on thermosetting resins has produced a furane resin which can be used to make low-pressure glass-fabric-base plastic laminates with flexural strength to 65,000 psi and edgewise compressive strength to 40,000 psi.

Liquid furane resin is said to have excellent wetting and penetrating qualities. When properly stabilized, it has been found to exhibit good storage characteristics.

Data Revealed On New Synthetic Rubber

Developed for the Army, a new synthetic rubber is said to have excellent resistance to oxidants and oils. Called "Kel-F" elastomer, the substance was developed by the M. W. Kellogg Co. It is a fluorocarbon polymer containing more than 50 per cent fluorine by weight that can be compounded, welded, mixed and extruded using standard rubber-progressing equipment.

Tests conducted recently indicate that "Kel-F" will be useful in fields requiring:

1. Extreme resistance to oxidants such as fuming nitric acid, oleum, 90 per cent hydrogen peroxide, ozone, oxygen and weather.
2. Thermal stability to 400 F.
3. Chemical resistance to oils at high temperature, excluding diester types, but including sour crudes, sulphur-bearing extreme-pressure lubricants, and silicones.
4. Very low moisture absorption, including electrical insulation.

According to Kellogg, "Kel-F" has excellent resistance to strong oxidizing mineral acids, peroxides, alkalies, titanium tetrachloride, alcohols, some chlorinated solvents and hydraulic fluids. X-ray diagrams have shown that the polymer is amorphous at temperatures as low as −40 C. There was no evidence of chain scission or halogen loss after prolonged exposure at 400 F.

Tensile strengths up to 3500 psi are said possible. Extensibility ranges from 400 to 600 per cent.

Among the items fabricated from "Kel-F" are hose, tubing, diaphragms, gaskets, O-rings and seals. Coated fabric has been made into protective clothing for personnel handling oxidant fuels.

Standards Engineers Society new officers for 1955 are: President, M. S. Gokhale, RCA Victor Div., RCA, Camden, N. J.; Vice-President, Herbert G. Arlt, Bell Telephone Labs., Murray Hill, N. J.; Treasurer, Victor S. Gittens, Philco Corp., Philadelphia, and Secretary, C. W. Bowler, Leeds & Northrup Co., Philadelphia.

Annual Conference for Engineers will be held by the College of Engineering, Ohio State University, on May 6. Practicing engineers and architects will meet with faculty, alumni and students to review the past year's technical developments and to look ahead to future developments. Conference speakers will

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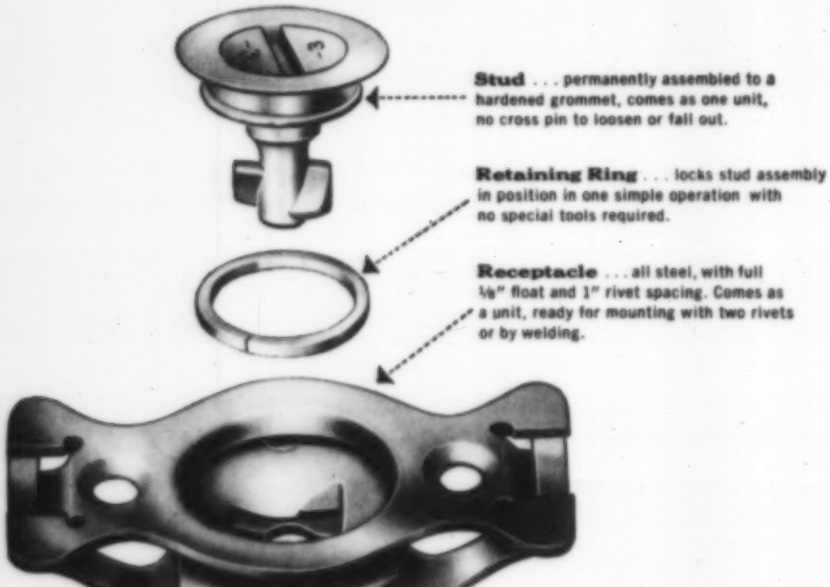
Panel Fastener!

PANELOC introduces Light-Weight, All-Steel Model, Setting Superior Standards in Tension and Shear at a new low price! Only three simple parts to inventory.


Stud . . . permanently assembled to a hardened grommet, comes as one unit, no cross pin to loosen or fall out.
Retaining Ring . . . locks stud assembly in position in one simple operation with no special tools required.
Receptacle . . . all steel, with full 1/8" float and 1" rivet spacing. Comes as a unit, ready for mounting with two rivets or by welding.

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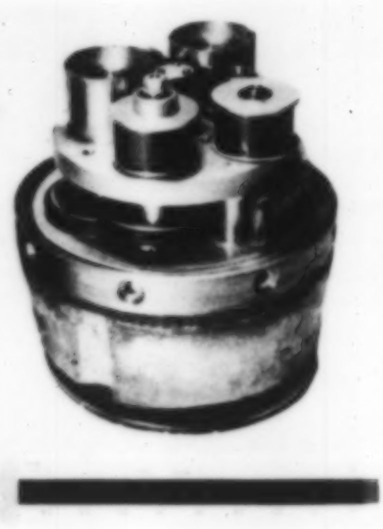
be John C. Sharp, president of Hotpoint Co., who will examine the challenges ahead for engineers in industry, and General Curtis E. Le May, who will present some of the nation's critical air defense problems from the engineer's point of view. Advance reservation information may be obtained from Associate Dean Harold A. Bolz, ACE General Chairman, College of Engineering, Ohio State University, Columbus, O.

Miniature Recorder Tapes Rocket Flight

Seven inflight performance characteristics may be tape recorded simultaneously with a newly developed miniature tape recorder. Made to be mounted inside the rocket, the device weighs only 5 pounds and is 4 inches in diameter by 6 inches long.



Data signals having a frequency range from dc to 50 cps may be recorded. An eighth recording channel is provided as a timing reference. Direct recording of thermocouple signals is said possible by North American Instruments Inc., designers of the unit.

Recording time is 90 seconds with ½-inch tape moving at a speed of 1½ inches per second. Modifications in speed, tape capacity and number of channels are said possible.

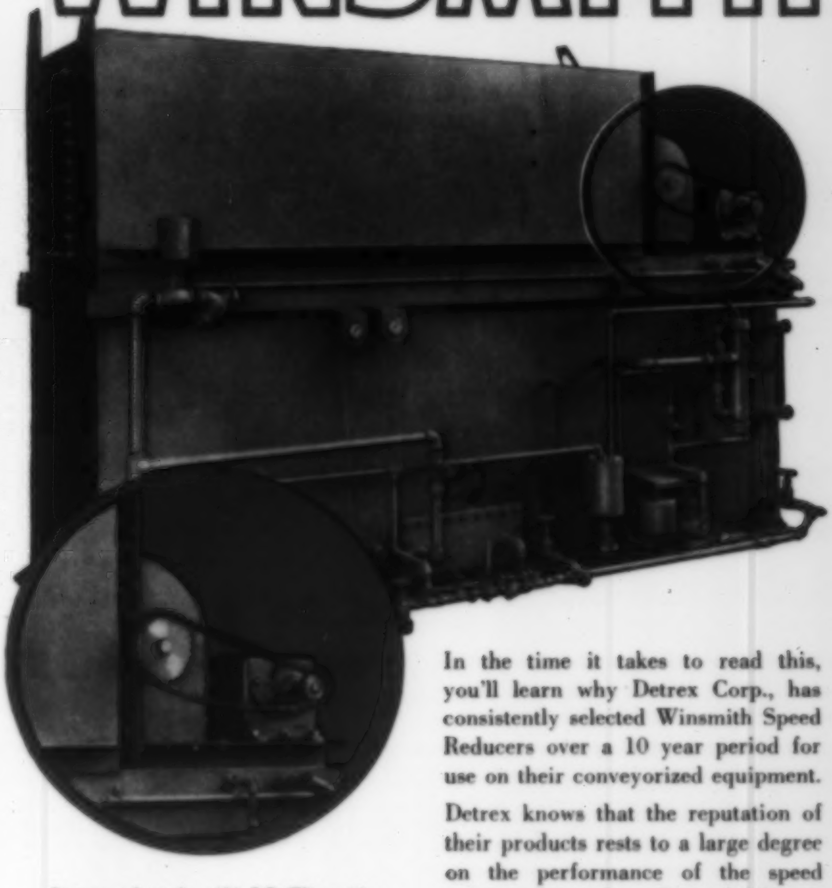
FANCY DESIGNS shown on this oscilloscope screen represent the answers to trigonometric problems being turned out by a new miniature all-transistor computer. Being designed especially for aircraft by Bell Telephone Laboratories, the new unit is expected to occupy less than 3 cubic feet of space and require less than 100 watts of operating power. Comparable vacuum-tube computers are said to need about 20 times that operating power

Navy Lab Develops New High-Aluminum Alloy Steel

Combining heat and oxidation resistance with excellent magnetic qualities and high electrical resistivity, a new ferritic type alloy that can be fabricated into thin, flexible, cold-rolled sheets has been developed at the Navy's White Oak Ordnance Lab.

Called Thermenol, the new compound is an iron-base alloy containing about 16 per cent aluminum and about 3 per cent molybdenum. Experments with 16-Alfenol, a previously developed binary alloy that could not be pro-

(*Continued on Page* 48)



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WINSMITH SPEED REDUCERS

Detrex selected a 4½ DB Winsmith Speed Reducer for use on their unique rotary basket gyro degreaser. Driven by a ¼ hp motor at 1750 rpm with a reduction ratio of 960 to 1, the Winsmith reducer provides a smooth, vibrationless operation that eliminates the possibility of damage to delicate machined parts.

In the time it takes to read this, you'll learn why Detrex Corp., has consistently selected Winsmith Speed Reducers over a 10 year period for use on their conveyorized equipment.

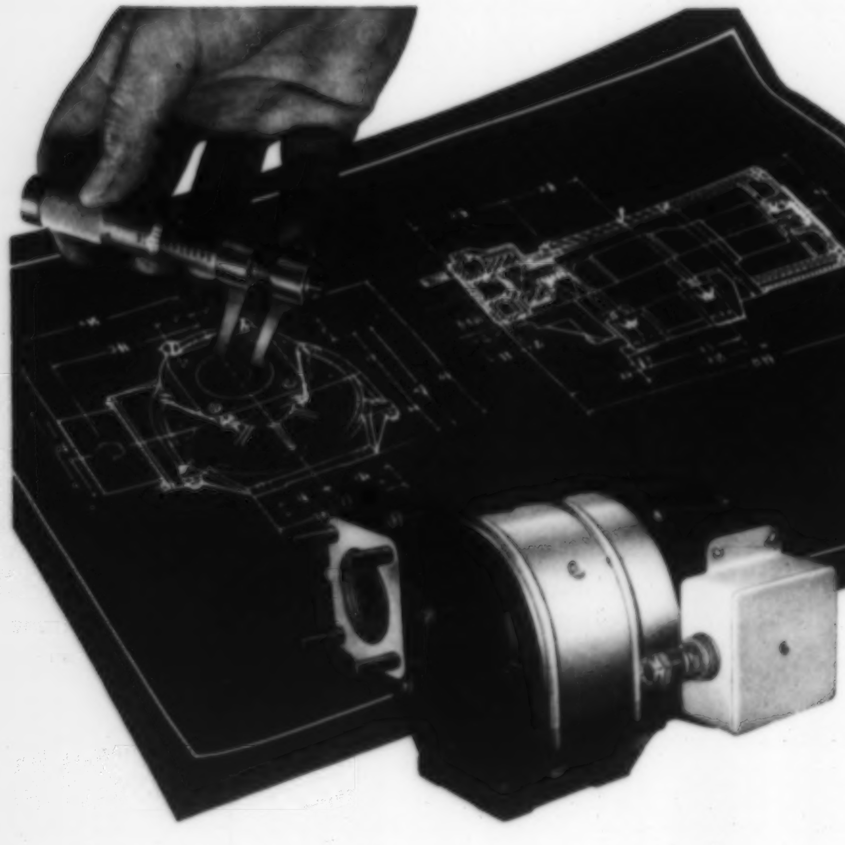
Detrex knows that the reputation of their products rests to a large degree on the performance of the speed reducer they select. *Dependability* is their prime specification . . . and, Detrex reports "Virtually no failures in 10 years" as the reason Winsmith Speed Reducers are continually used on equipment carrying the Detrex Name Plate!

Apply this 10 year record of dependability to your own speed reducer problems! In addition to ruggedness and reliability, you can count on Winsmith for the most complete line of speed reducers from a single source within the range of 1/100 to 85 hp. in ratios of 1.1:1 to 50,000:1. A Winsmith power transmission specialist is available to discuss your speed reducer applications. You'll find him listed in the classified section of your phone directory; or, write Winsmith, Inc. direct.

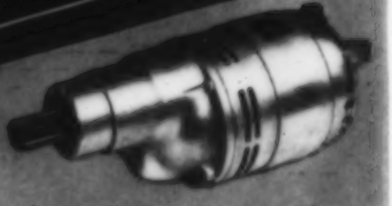
...a single source for the most complete line of speed reducers within the range of 1/100 h.p. to 85 h.p. in ratios of 1.1:1 to 50,000:1

WINSMITH SPEED REDUCERS

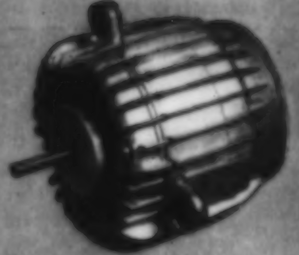
WINSMITH, INC.
16 Elton St.
Springville, (Erie County) N. Y.



Motor with shaft on double row ball bearings for high speed grinder.



Low weight, geared head motor for many slow-speed, heavy-duty drives.



An outstanding hair dryer motor. Design insures quiet, vibrationless operation.

Motor parts for floor polisher. Adaptable to food mixers and other home appliances.

If you are interested in any of the above motors write and we shall be glad to send full information.

a motor designed to your exact product requirements

Many manufacturers of motor-driven products have found that the use of a Lamb Electric *special application* motor results in better products and lower costs.

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FRACTIONAL HORSEPOWER **MOTORS**

Mass-Produced at Less Cost...

by HAYNES Investment Casting
Trade-Mark

PRODUCED FOR 74 PER CENT LESS

Originally this turbine wheel was machined from a 20-lb. forging to a final weight of a little over 1 lb. Now the part is produced by investment casting and only 2 oz. of metal is removed. Investment casting has brought about a 74 per cent reduction in production costs by saving strategic metal and machine time.

COST CUT 60 PER CENT

This investment-cast motor mount was made in a high-strength alloy at 60 per cent less than the cost of a forging. The mount bears the entire weight and torque of a 100-lb., 15-horsepower aircraft starter motor. The investment-cast parts require only four simple finishing operations.

ASSEMBLY COSTS REDUCED

Investment casting made it possible to produce this cylinder head in one piece, eliminating extra assembly costs. Machining was reduced to a minimum. The design of the part is special to investment casting. The castings weigh about 25 lb. and are 7 in. in diameter.

HAYNES *investment castings can solve some of your own production problems. For more information, contact the nearest Haynes Stellite Company office listed below.*

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Sound, dense, high-strength parts available in cobalt-base alloys, nickel-base alloys, iron-base alloys, stainless steels, and alloy and carbon steel.

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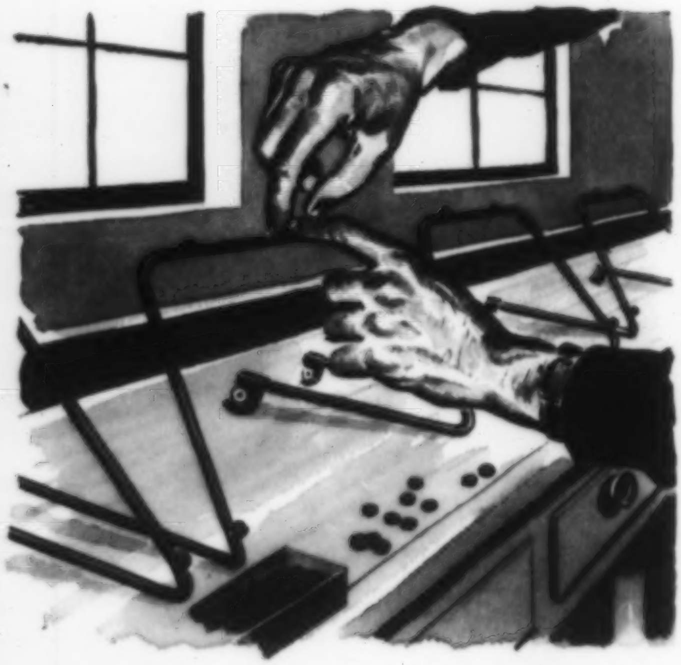
SHOCK-ABSORBING
SKID-PROOFING
CUSHIONING
NOISE-KILLING
SCRATCH-PREVENTION

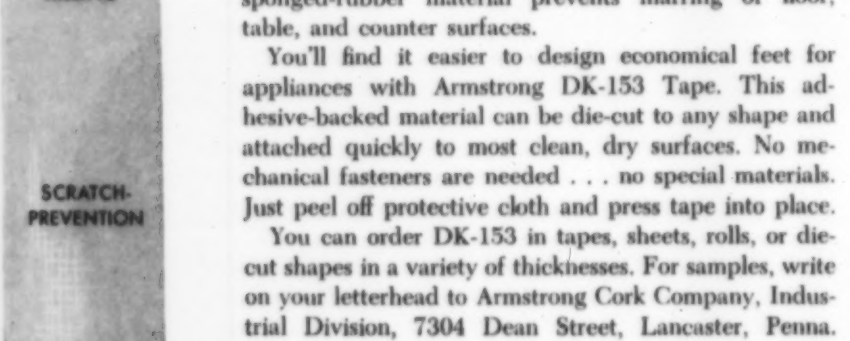


Vibration-damping

Appliance feet made of Armstrong DK-153 Tape isolate and damp disturbing vibration . . . make appliances run smoother, quieter. In addition, this resilient, cork-and-sponged-rubber material prevents marring of floor, table, and counter surfaces.

You'll find it easier to design economical feet for appliances with Armstrong DK-153 Tape. This adhesive-backed material can be die-cut to any shape and attached quickly to most clean, dry surfaces. No mechanical fasteners are needed . . . no special materials. Just peel off protective cloth and press tape into place.

You can order DK-153 in tapes, sheets, rolls, or die-cut shapes in a variety of thicknesses. For samples, write on your letterhead to Armstrong Cork Company, Industrial Division, 7304 Dean Street, Lancaster, Penna.



Armstrong DK-153 TAPE

(*Continued from Page* 45)

duced in usable sheet form, resulted in the fabrication of this and other high-aluminum alloys. All are capable of being cold-rolled into thin, flexible sheets.

Thermenol is oxidation resistant at temperatures as high as 2300 F. It is said to exhibit good corrosion resistance to oxidizing solutions and atmospheric conditions. Polished samples of Thermenol tested by constant exposure to the atmosphere and handled daily for about a year still retained their polished appearance.

These qualities, together with its low density, make the metal useful as a substitute for stainless steel in some aircraft and jet-engine applications. Tests indicate it has properties superior to most ferritic stainless steels and is not far below values obtained for austenitic stainless steel.

High electrical resistivity of Thermenol is expected to make it useful as a material for resistance heating elements. Its magnetic properties and wear resistance promise usefulness in magnetic applications. In addition, Thermenol can be machined at room temperature, and can be arc or spot welded without difficulty.

Meetings

AND EXPOSITIONS

Apr. 18-21—

American Management Association. Packaging conference to be held at the Palmer House, Chicago, Ill. Additional information may be obtained from society headquarters, 330 West 42nd St., New York 36, N. Y.

Apr. 18-21—

American Society of Mechanical Engineers. Spring meeting to be held at the Lord Baltimore Hotel, Baltimore, Md. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

Apr. 25-27—
Association of Iron & Steel Engineers. Spring conference to be held at the Statler Hotel, Detroit, Mich. Managing director is T. J. Ess, 1010 Empire Bldg., Pittsburgh 22, Pa.

Apr. 27-29—
Society for Experimental Stress Analysis. Spring meeting to be held at Hotel Statler, Los Angeles, Calif. Secretary-treasurer is W. M. Murray, P. O. Box 168, Central Square Station, Cambridge 39, Mass.

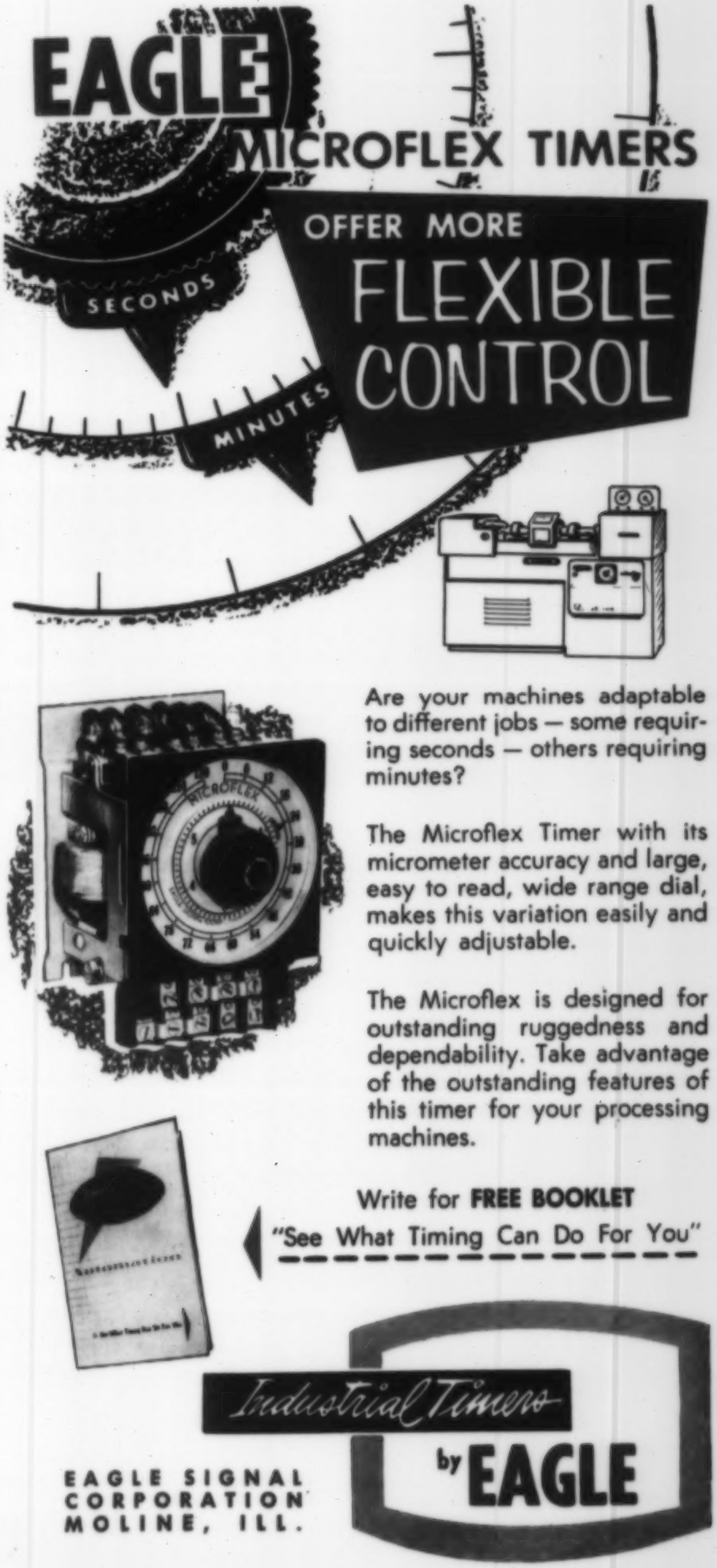
Apr. 28-29—
American Zinc Institute Inc. Annual meeting to be held at the Drake Hotel, Chicago, Ill. Additional information may be obtained from society headquarters, 60 East 42nd St., New York 17, N. Y.

May 4-7—
National Screw Machine Products Association. Annual meeting to be held at Hotel Statler, Buffalo, N. Y. Additional information may be obtained from society headquarters, 2860 East 130th St., Cleveland 20, O.

May 7-15—
Society of the Plastics Industry, Inc. Annual conference, convention cruise aboard *Queen of Bermuda* to Havana, Cuba and Nassau, B. W. I. Additional information may be obtained from society headquarters, 67 West 44th St., New York 36, N. Y.

May 10-11—
American Institute of Electrical Engineers. Sixth annual appliance technical conference to be held at Hotel Hollenden, Cleveland, O. Additional information may be obtained from society headquarters, 33 West 39th St., New York 18, N. Y.

May 10-12—
Metal Powder Association. Annual meeting and exhibit to be held at the Bellevue-Stratford Hotel, Philadelphia, Pa. Additional information may be obtained from society headquarters, 420 Lexington Ave., New York 17, N. Y.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The Microflex Timer with its micrometer accuracy and large, easy to read, wide range dial, makes this variation easily and quickly adjustable.

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...are an ideal solution to all types of right angle needs, and are especially adaptable to confined areas. They're small, rugged, quiet, and precision made.

Crown Gear Units have matched "Zerol" hardened gears which are mounted in double shielded ball bearings, and completely enclosed. Re-lubrication, if necessary, is easily accomplished, and four or five mounting flanges provide easy installation.

Special models will be engineered and quotations submitted for any specific problems. Write today for the name of your local distributor. Crown Gear Units are available almost everywhere.

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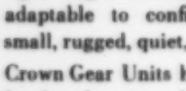

Over 120 leading distributors in 43 states, Crown Mitre Gear Units are where you want them ...when you want them.

Sold in Canada by H. R. Arms Ltd.
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Engineering News Roundup

May 16-20—

Materials Handling Exposition to be held at the International Amphitheatre, Chicago, Ill. Details are available from Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

May 23-25—

American Society for Quality Control. Annual meeting and exhibit to be held at the Statler Hotel, New York. Additional information may be obtained from society headquarters, 50 Church St., New York 7, N. Y.

May 23-25—

American Foundrymen's Society. Annual meeting to be held at the Rice-Shamrock Hotel, Houston, Texas. Additional information may be obtained from society headquarters, 616 South Michigan Ave., Chicago 5, Ill.

May 30-June 10—

Canadian International Trade Fair to be held at Exibition Park, Toronto, Ontario, Canada.

June 5-8—

American Gear Manufacturers Association. Annual meeting to be held at The Homestead, Hot Springs, Va. Additional information may be obtained from society headquarters, One Thomas Circle, Washington, D. C.

June 7-10—

American Welding Society. National spring meeting and exposition to be held at the Municipal Auditorium, Kansas City, Mo. Additional information may be obtained from society headquarters, 33 West 39th St., New York 18, N. Y.

June 12-15—

American Society of Agricultural Engineers. Annual meeting to held at the University of Illinios, Urbana, Ill. Secretary is Frank B. Lanham, Saint Joseph, Mich.

June 16-18—

Malleable Founders' Society. Annual meeting to be held at The Greenbrier, White Sulphur Springs, W. Va. Additional information may be obtained from society headquarters, Union Commerce Bldg., Cleveland 14, O.

June 19-23—

American Society of Mechanical Engineers. Diamond Jubilee Semi-Annual Meeting to be held at Hotel Statler, Boston, Mass. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

June 20-23—

American Electroplaters' Society. Forty-second annual convention and Industrial Finishing Exposition to be held at the Public Auditorium, Cleveland, O. Exposition managers are Harold E. Bartlett and Albert W. Erickson, American Decorating Co., 1849 West 24th St., Cleveland 13, O.

June 21-24—

Institute of the Aeronautical Sciences. Fifth International Aeronautical Conference to be held at the IAS Bldg., Los Angeles, Calif. Additional information may be obtained from society headquarters, 2 East 64th St., New York 21, N. Y.

June 27-July 1—

American Institute of Electrical Engineers. Summer General Meeting to be held at New Ocean House, Swampscott, Mass. Additional information may be obtained from society headquarters, 33 West 39th St., New York 18, N. Y.

June 26-July 1—

American Society for Testing Materials. Annual meeting to be held at the Chalfonte-Haddon Hall, Atlantic City, N. J. Executive secretary is R. J. Painter, 1916 Race St., Philadelphia 3, Pa.

July 12-14—

Western Plant Maintenance & Engineering Show to be held at the Pan Pacific Auditorium, Los Angeles, Calif. Additional information may be obtained from Clapp & Poliak Inc., 341 Madison Ave., New York 17. N. Y.

MEN
OF MACHINES

Appointment of **C. V. Crockett** as chief engineer of the GMC Truck and Coach Div., Pontiac, Mich., has been announced by General Motors Corp. Formerly chief engineer of the Cadillac Cleveland Tank Plant, Mr. Crockett succeeds **C. J. Bock,** who is on leave of absence because of illness. A graduate of Purdue University, Mr. Crockett joined the company's Cadillac Motor Div. in 1924. The next year he was assigned to the engineering laboratory to do research work on carburetion and in 1927 became engineering secretary. His next appointment was that of staff engineer in charge of the patents and new devices department; later he served as head of the technical data section. In 1941 Mr. Crockett was placed in charge of tank armament, handling that assignment throughout World War II. Subsequently he was named assistant chief engineer of the tank plant and was appointed chief engineer in 1951. He is a member of the Society of Automotive Engineers and the American Ordnance Association.

C. V. Crockett

H. Erich Nietsch has been elected vice president in charge of project development of Robinson Aviation Inc., Teterboro, N. J. Mr. Nietsch was in charge of structural vibration research work for the Glenn L. Martin Co. and served on the NACA Subcommittee on Vibration and Flutter and on the AIA Committee on Noise Control. He joined Robinson in 1950 as assistant to the president and in 1953 was made manager of the Industrial Div.

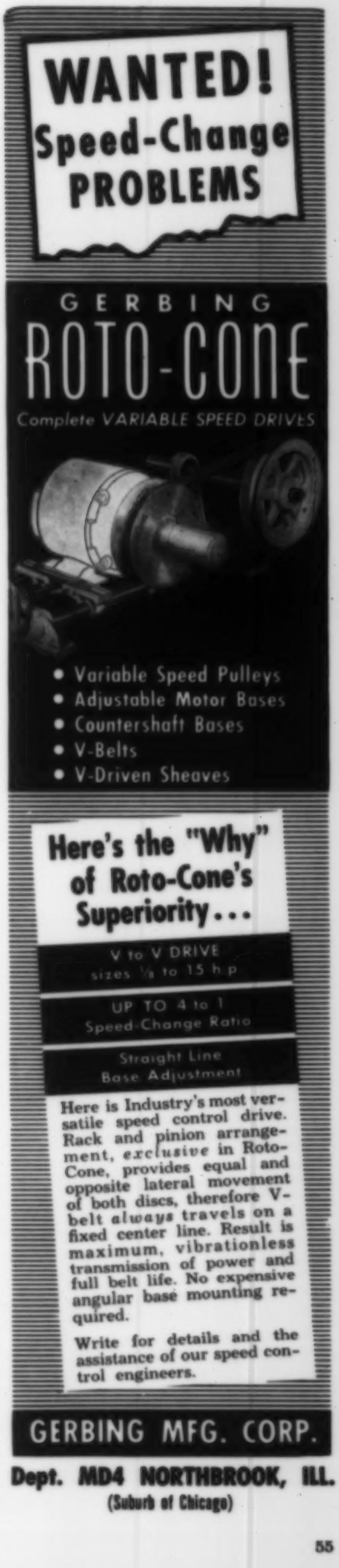
Kurt O. Tech, chief engineer of the Cross Co., Detroit, has been elected to the company's board of directors.

Barry Corp., Watertown, Mass., has announced the appointment of **Russell T. Lowe** as assistant chief engineer and **Richard D. Cavanaugh** as technical assistant to chief engineer **Charles E. Crede.** Mr. Cavanaugh will act as technical adviser to project engineers, and Mr. Lowe will be directly responsible for all operating functions of the engineering department.

Formerly chief mechanical engineer, **James J. Marino** has been named vice president in charge of engineering by Motordyne Inc., Los Angeles.

Teleregister Corp., New York, recently appointed **Samuel Levine** to the position of systems engineer.

Melvin P. Espy has been appointed to the newly created position of assistant director of engineering at the Anaheim, Calif., division of Northrop Aircraft Inc. Mr. Espy served for three and one-half years


WANTED!
Speed-Change PROBLEMS

GERBING
ROTO-CONE
Complete VARIABLE SPEED DRIVES

- Variable Speed Pulleys
- Adjustable Motor Bases
- Countershaft Bases
- V-Belts
- V-Driven Sheaves

Here's the "Why" of Roto-Cone's Superiority...

V to V DRIVE sizes ⅛ to 15 h.p.

UP TO 4 to 1 Speed-Change Ratio

Straight Line Base Adjustment

Here is Industry's most versatile speed control drive. Rack and pinion arrangement, *exclusive* in Roto-Cone, provides equal and opposite lateral movement of both discs, therefore V-belt *always* travels on a fixed center line. Result is maximum, vibrationless transmission of power and full belt life. No expensive angular base mounting required.

Write for details and the assistance of our speed control engineers.

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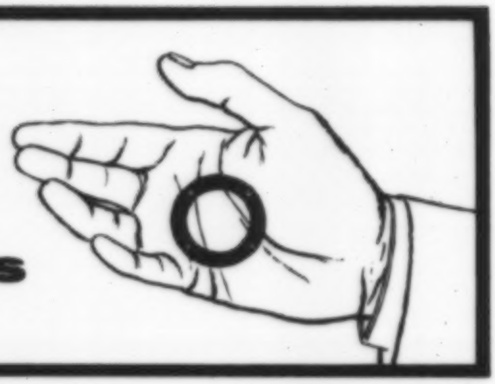
Dept. MD4 NORTHBROOK, ILL.
(Suburb of Chicago)

from

Grease Retainers



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Whether you want to hold grease in, filter air or provide a wicking method, you'll find the answer in Felt by Felters.

FELTERS S.A.E. F-26 is a felt suitable for packing or padding when held in place by other materials, but is not recommended for mechanical purposes.

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. . . or cut exactly as you want it.

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FELT & FELT PRODUCTS
DESIGN BOOK
THE FELTERS COMPANY

as chief of the special weapons section for Canadair Ltd., and for 12 years prior to that time was employed in engineering with the Glenn L. Martin Co.

Francis T. Greenup was recently named chief design engineer by Consolidated Engineering Corp., Pasadena, Calif. Mr. Greenup will direct activities of a section responsible for new product design, engineering drafting and instrument model development.

Audio Products Corp., Los Angeles, has appointed **Hugh Pruss** to the position of chief engineer. Mr. Pruss joined the company last year as head of the Telemetering Research and Development Div. He was previously technical operations director and chief engineer of the Telemetering Div. of Raymond Rosen Engineering Products Inc., Philadelphia.

Recent promotions at American Cast Iron Pipe Co., Birmingham, Ala., include those of **Stephen D. Moxley**, who has been named president, and **Kenneth R. Daniel,** who is now vice president and chief engineer.

Kurt A. Beier has been named vice president in charge of engineering and research by Schwitzer-Cummins Co., Indianapolis.

William L. Davis Jr. has been appointed assistant vice president of engineering by Emerson Electric Mfg. Co., St. Louis. He will be responsible for armament engineering.

Russell J. Geitman has been appointed chief engineer of the Link-Belt Company's plant in San Francisco. He will direct the design of all equipment made at this plant. Mr. Geitman has been associated with Link-Belt since graduating from Armour Institute (now Illinois Institute of Technology) with a degree in mechanical engineering in 1928. After working at each of the company's two plants in Chicago, he served as a sales engineer at district offices in St. Louis, Cleveland and Chicago. Since 1948

Russell J. Geitman

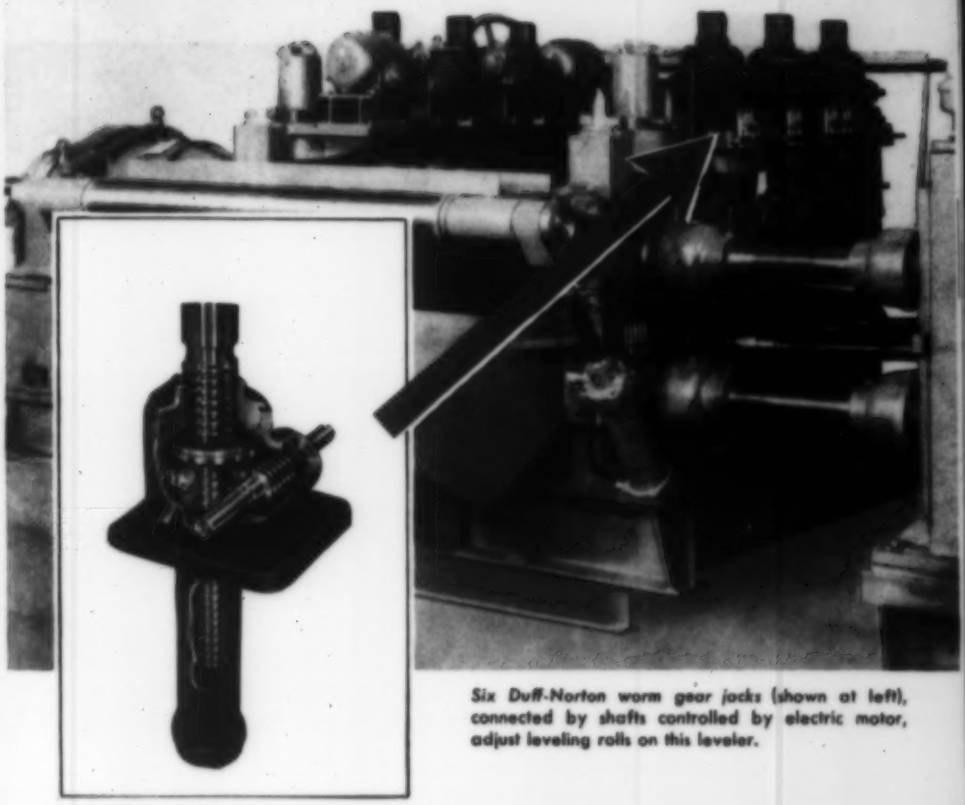
he has specialized in the design and application of foundry and steel mill equipment, with headquarters at Chicago. Mr. Geitman is a member of the American Society of Mechanical Engineers, the American Foundrymen's Society and the Association of Iron and Steel Engineers.

Dravo Corp., Pittsburgh, has announced the appointment of **H. W. North** as chief engineer of the newly established process equipment department of its Engineering Works Div. The new department will design, fabricate and market pressure vessels, mixers, blenders, filtering equipment and related machinery.

Bohumir Larys has been appointed chief electrical engineer on the staff of Rotron Research Corp., affiliate of Rotron Mfg. Co., Woodstock, N. Y. He will be responsible for the design and development of electrical components to be used in the manufacture of the company's line of cooling devices for the electronics industry.

Rochester Products Div. of General Motors Corp., Rochester, N. Y., has appointed **E. A. Kehoe** director of quality control.

Robert M. Wilson Jr. has been named development engineer in the power field for the Development



Six Duff-Norton worm gear jacks (shown at left), connected by shafts controlled by electric motor, adjust leveling rolls on this leveler.

Here's a time-tested device for adjusting machinery

It's the Duff-Norton worm gear jack, successfully used by many machine builders as a component of equipment for precise, positive control of linear motion; applying pressure; resisting impact. Two or more of these jacks can be connected by means of shafting and mitre gear boxes or any power-operated positive control system, so that jacks always raise or lower under equal or unequal loads in perfect unison. Capacities range from 5 to 35 tons with any raise up to 25 inches; worm gear ratios, 8:1 to 45:1; turn of worm for each 1 inch raise, 10 to 180; available in either Acme or square threads. Screw ends and tops are available in many types and can be readily adapted to your specific requirements.

Duff-Norton worm gear jacks have been specified by America's leading designers and machinery builders for many years. They are made in 6 standard sizes or to your special order. Write for booklet!

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Please send immediately a free copy of your Worm Gear Jack Booklet.

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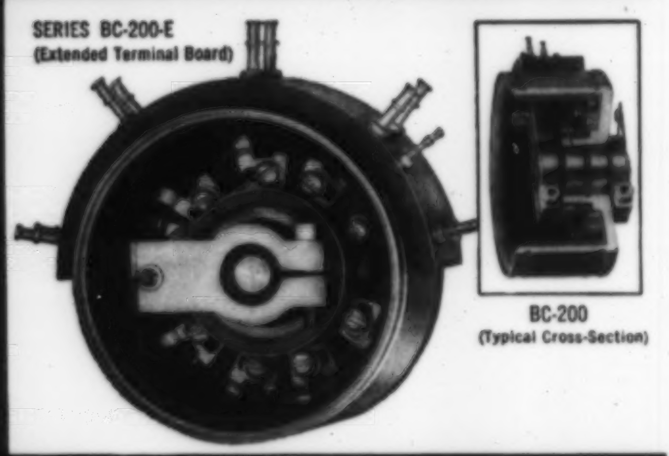

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and Research Div. of International Nickel Co. Inc., New York.

The Swartwout Co., Cleveland, has appointed **Joseph P. Green** director of engineering. Mr. Green will fill a new position established to provide unified supervision of the company's Autronic Control, Power Plant Equipment and Industrial Ventilation divisions. Prior to joining Swartwout in 1953 as chief engineer in the application engineering department, he was chief instrument engineer at H. K. Ferguson Co. He also has been associated with Bailey Meter Co. and the General Electric Co. Mr. Green graduated from Case Institute of Technology with a B.S. degree in electrical engineering. He is an active member of the Instrument Society of America, having served as chairman of the Production Processes Committee last year.

Joseph P. Green

Frank R. Benedict has been appointed manufacturing engineering manager for the Sturtevant Div. of Westinghouse Electric Corp., Pittsburgh.

Borg-Warner Corp., Chicago, recently announced new appointments in several of its divisions. **Charles Edward Cooney Jr.** has been named chief engineer of the Mechanics Universal Joint Div.; **A. H. Schmal** has been appointed manager, and **John Polomski,** chief engineer of the Products Development Laboratory in Detroit; and **A. A. Mathewson** has been named assistant to the president of the Petro-Mechanics Research Div. at North Hollywood, Calif.

Lawrence S. Brown has rejoined Ford Instrument Co., division of Sperry Corp., Long Island City, N. Y., as a project engineer. Mr. Brown had formerly spent 19 years with the company in test, field service and design engineering.

Nelson F. Bump has been elected vice president of manufacturing and engineering of Hohl Machine & Conveyor Co. Inc., Buffalo. He formerly was chief engineer of Caro Co.

Malsbary Mfg. Co., Oakland, Calif., has appointed **F. Hirsch** to the position of director of research.

Robert G. Hess has been appointed vice president of operations of the Pesco Products Div. of Borg-Warner Corp., Bedford, O.

Reorganization of Mark Simpson Mfg. Co., Long Island City, N. Y., has resulted in the appointment of **Joseph Rice** as assistant chief engineer and **William Lipson** as coordinating engineer.

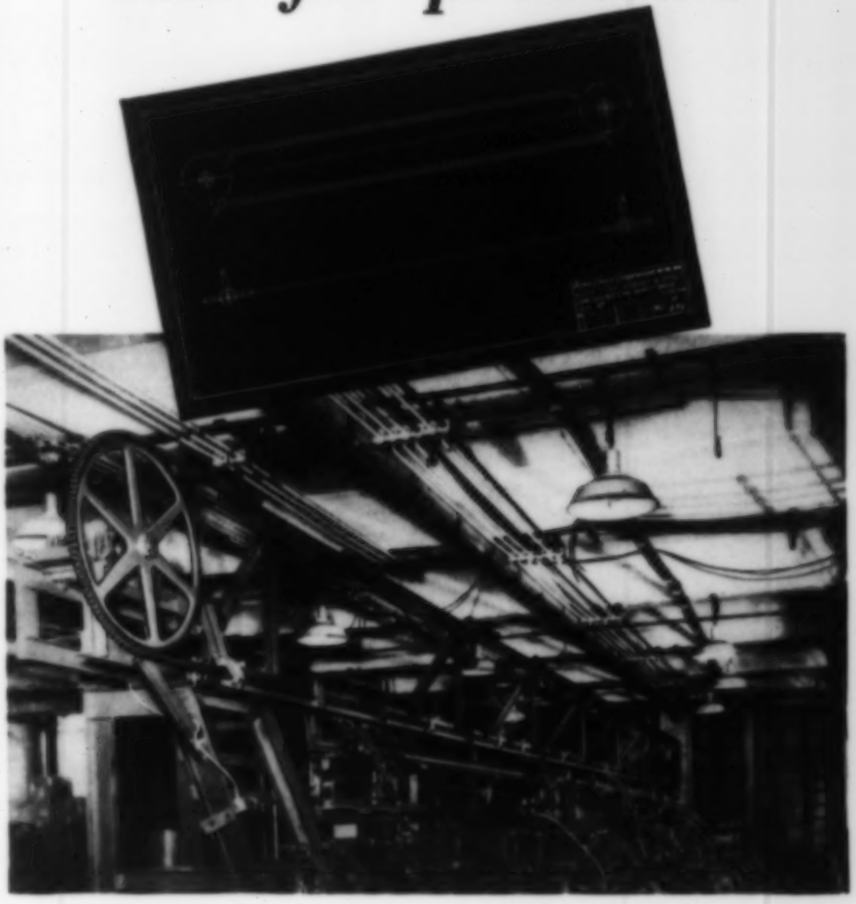
Louis W. Brohman has been appointed chief engineer of Renois Tying Machines Inc., Melrose Park, Ill. He was formerly chief engineer of Gerrard Steel Strapping Div., U. S. Steel Corp.

Chief engineer since 1951, **Theodore J. Zeller** has been elected vice president in charge of operations of Mack Trucks Inc., with headquarters at Allentown, Pa.

G. **Lupton Broomell Jr.** was recently appointed chief engineer of Leeds & Northrup Co., Philadelphia.

John D. Gordon has been appointed director of manufacturing engineering by Studebaker-Packard Corp., Detroit.

ACME
asks for problems



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MACHINE DESIGN

APRIL 1955

How To Create A Shortage of Engineers

HELP-WANTED ads for design engineers continue to crowd the pages of our daily newspapers. Possibly mistaking a symptom for a disease, many people including much of management personnel keep crying "shortage of engineers."

What do working engineers themselves say? Those with whom we have talked and who have written to us say that the "shortage" is phony. They say it could disappear overnight if the management of industry would come to grips with facts.

Dissatisfaction and restlessness prompt engineers to seek greener pastures. Thus the high volume of want-ads may simply reflect the large turnover in engineering employment. High turnover in such a specialized activity means inefficiency. Inefficiency creates a need for more engineers than should be necessary, lending credence to the "shortage" theory.

Prime cause for dissatisfaction (there are others) is inadequate salary level. A new study just published by the NSPE and titled *A Professional Look at the Engineer in Industry* includes some telling statistics on income trends, which serve to corroborate what many engineers already know.

For instance, in 1940 an engineer with 15 years' experience was receiving 1.95 times the pay of skilled labor. Eleven years later the ratio was only 1.25. Corresponding figures for an engineer with 5 years' experience were 1.20 in 1940 and 0.94 in 1951. Because skilled labor wages closely follow the cost of living, these figures are a good index to engineers' real income.

Again, professional engineers at age 40 are making about 1.8 times current starting rates. At age 55 the ratio is only about 2.0. But if engineers who have gone into management are excluded from the analysis, the ratio at age 55 is no more than that for age 40—and frequently less. Is an engineer with 15 to 30 years' experience actually worth less than twice a youngster just out of college?

The conclusions are obvious. Is it fair to expect a seasoned, competent engineer to "beat his brains out" and try to live and act as a professional man should—with a diminishing real income. Naturally he tries to improve his lot by bargaining—either individually with other employers, or collectively with his present employers.

As the engineer reaches the age when his engineering knowledge and experience become most effective, what does he find? His salary has become static. Who can blame him if he seeks or accepts economic advancement through activities in management or sales rather than in engineering, where his heart may nevertheless still lie?

When that happens, the shortage becomes real.

Colin Carmichael

EDITOR

How to program

Design Evaluation—*to insure*

By J. S. McChesney

Senior Design Engineer, Minneapolis-Honeywell Regulator Co.
Brown Instruments Div., Philadelphia, Pa.

GOOD PRODUCT design is the prerequisite to good product sales. Without a well designed product a manufacturer cannot exist in a highly competitive market. To insure a well designed product, engineers responsible for development of a product, *Fig.* 1, must satisfy four basic objectives.

1. The product must meet with customer acceptance.
2. The product must be a sound economical investment.
3. The product must be serviceable.
4. The product must be available to meet production schedules and delivery dates.

Whether the product is a new design or a redesign, these objectives are always the same.

Adequate design evaluation during specific stages of the development program can insure a product that not only meets design specifications but also these four objectives. Such an evaluation is a continuous process and seldom stops although normally its maximum effectiveness has been reached by the time the design is frozen.

This article will review in some detail the considerations that are important in an adequate design evaluation which will result in the best possible product.

Customer acceptance: Every product designed has, ultimately, a customer—from the housewife to the industrialist. In every case the approach to a good product design that will satisfy the aim of customer acceptance is the same. The design must have an acceptable appearance, it must have satisfactory performance, it must be better than competition, and it must be relatively easy to operate and use by the individuals for whom it has been designed.

Appearance should never be underestimated in designing for customer acceptance. The customer will probably see an illustration in an advertisement, a display model, or a sample long before the fine print about performance and price is read. An evaluation of the design based on size, shape, and color will be made and whether consciously or not, definite opinions will be formed on the basis of this first impression.

Therefore, an experienced industrial designer should be consulted during the initial stages of the design program. Working closely with the project engineer and designers, he can evaluate the layouts and aid in directing the design down ac-

Design Evaluation At Work

Fig. 1—A successful product results from adequate design evaluation during all stages of product design and development. Cooperation and interchange of ideas among designer, methods engineer, industrial designer, project engineer, test engineer and application engineer are a necessary part of the design evaluation process

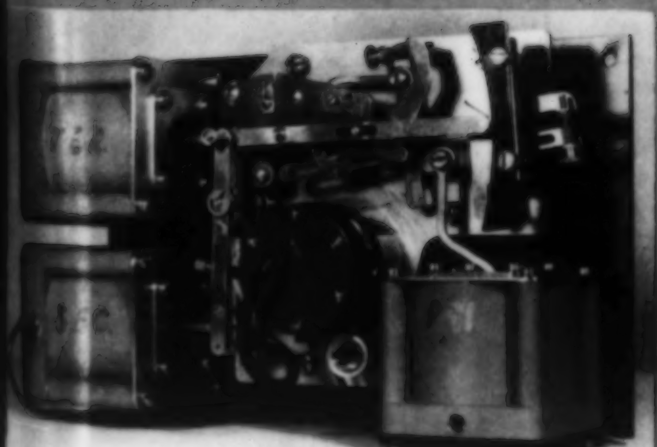
Sales
Profit
Performance
Delivery

ceptable paths. As details materialize, that will affect appearance, the industrial designer should continue to perform his design evaluation so that the finished product will have the best appearance possible for the most economical methods of manufacturing available.

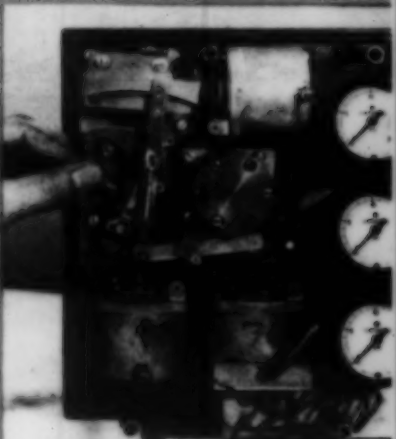
It is necessary, of course, to support the industrial designer's efforts with a satisfactory functional device. Once the customer has stopped to inspect the product, his concern becomes that of performance. He wants the best possible product for his money. Thus excellent performance becomes important and generally stands out as the most important consideration of any development program.

A continuous design evaluation will insure that the product when finally released for production will meet performance specifications established at the beginning of the development program. Often an intelligent evaluation made in the early design stages when only layouts and details are available, will reduce the number of wrong paths

A preliminary model of the Tel-O-Set automatic ratio relay provided performance data to confirm feasibility of the basic design. With this breadboard model as the starting point . . .



. . . an experimental model was constructed from preliminary drawings. Experimental tests, methods, tool and cost evaluations as well as design and performance evaluations were then conducted. Evaluation of the design brought out a number of objections. Parts were too crowded. Thumb-screw calibration adjustments, screws, and pressure fittings were relatively inaccessible. Two expensive manifold blocks, one for the gages, the other to provide for external piping, had an excessive number of interconnecting tubings. Tool and parts cost as well as assembly and servicing operations would be adversely affected. Redesign was essential



into which a product design may wander. Such an evaluation may eliminate expensive changes and project delays at a later date when dollars and days become all-important.

While it is difficult to predict performance from layout and detail drawings before a model has been built and tested, experience gained from previous designs and similar products can be utilized to reduce design shortcomings. Elimination of designs and details which have previously caused trouble and the incorporation of tried and proved designs and details can save many hours of delay for redesign because of poor performance.

Pressure from competition is never-ending. If a customer cannot find what he wants in the way of appearance and performance in one manufacturer's product, he will turn to competition. Here once again, design evaluation becomes important because not only does one's own product have to be analyzed but the competitor's product as well. Features of appearance, performance, and price must be better. A continuous evaluation of a competitor's product, including changes in newer models, with an understanding of the product's shortcomings, must be undertaken to insure that one's own product—still in its design stages—not only will be better than what competition has on the market but better than any under development.

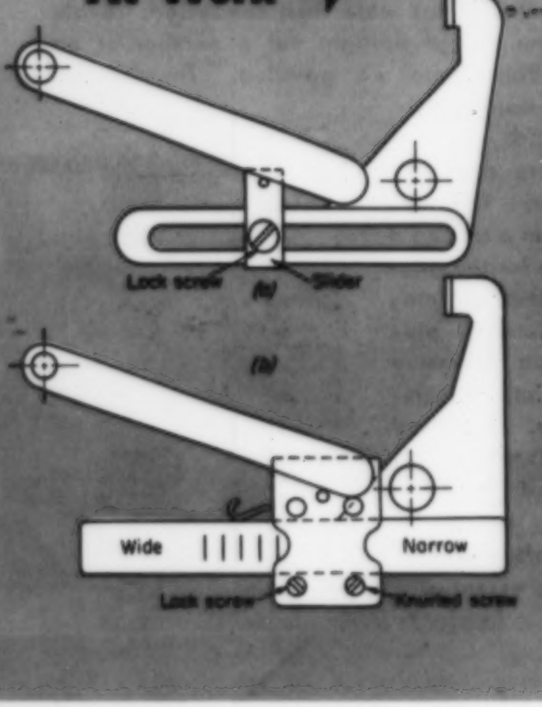
Acceptability of a product for use once a customer has been attracted by its appearance, performance, and superiority to competitive goods will be based upon its ability to be used and operated effectively. It must be relatively easy to operate by the customer and must have not more nor less than the necessary adjustments and features required to do the job for which it was purchased. The accessibility of knobs, switches, routine adjustments, and other specific features are important design considerations. A design evaluation must then take into consideration even these features at the earliest stage possible to insure a satisfactory product.

Economics: Second objective of a design program is a product that is a sound economic investment. By performing a design evaluation which takes into consideration the cost of the product versus the selling price, an expensive, low-profit product, which would be totally unsatisfactory, can be avoided. In a design evaluation for cost reduction there are a number of factors which should be considered which can reduce tool, parts, handling, and assembly costs.

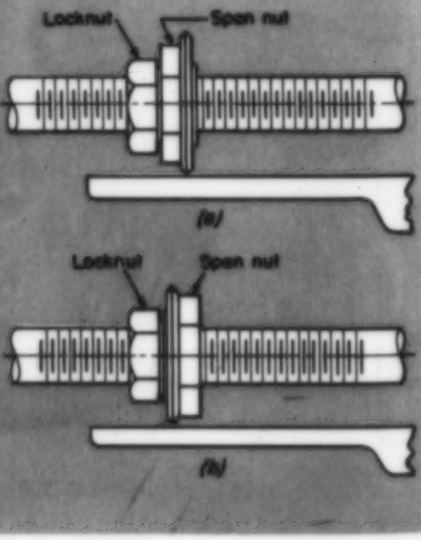
Good parts design is one of the biggest areas where cost can be reduced. Costly machining and complicated tooling of parts can soon make the cost of the product unreasonably high. The need

Design Evaluation At Work

In the redesign process, a span adjustment was changed to reduce calibration time. The original lock screw slider adjustment (a) was difficult to move and lock. Fine adjustment was impossible. In the improved version (b) a knurled screw when turned moves the span adjustment along the arm much like a rack and pinion, providing very fine adjustment. A lock screw is provided to retain the adjustment. Markings indicate direction adjustment should be moved to obtain the desired result. Although the redesigned parts cost more, calibration time reduction more than offset the increased cost. Additionally, recalibration by the customer, if necessary, is simplified



Another span adjustment change eliminated the need for a special tool by the customer. As originally proposed (a) a special thin wrench was required to unlock and lock the adjustment. By simply turning the nut around (b), a standard wrench can be used



for expensive fabrication operations should be examined and evaluated. Often by combining parts and simplifying design, unnecessary parts, costly operation, and excessive handling are eliminated with a resulting compact superior product. Evaluation of material and finishes used may not only reduce cost but may eliminate part failures and poor appearance with the inevitable customer dissatisfaction.

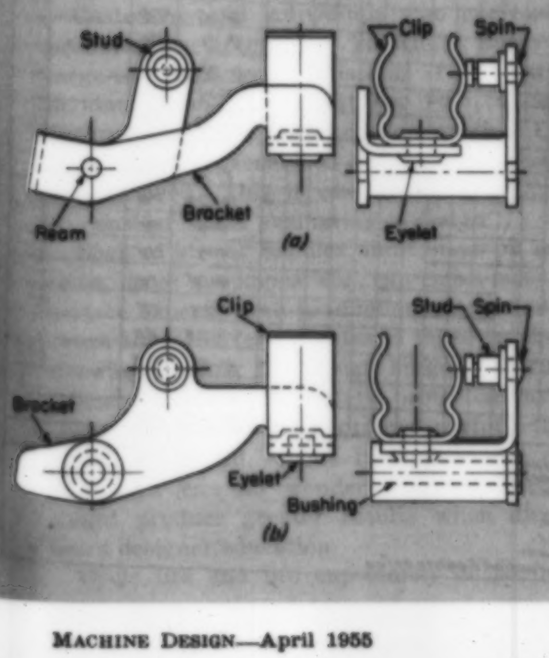
Extra features added to improve sales to a few, specific, limited customers, or to improve appearance may be costly additions which might seriously handicap the total profit picture of the product. Need versus cost of such features must be carefully evaluated.

Intelligent use of standard parts, parts already tooled and in production, can save the added cost of new tooling and double stocking of nearly identical parts. In addition the increased annual usage of certain parts might easily reduce the unit cost of the item by changing manufacturing operation, such as from hand screw machines to automatic screw machines. These are the tangible savings. Intangible savings appear as reduced drafting time of detail parts, reduced tool design time and tool making and reduced initial delivery time of purchased parts such as castings and forgings, with the resulting earlier delivery date of the new product. The use of standard "tried and proven" parts minimizes the inevitable production and servicing problems that develop in any new product. Here, once again, a careful design evaluation in the form of a standard parts review can improve the product.

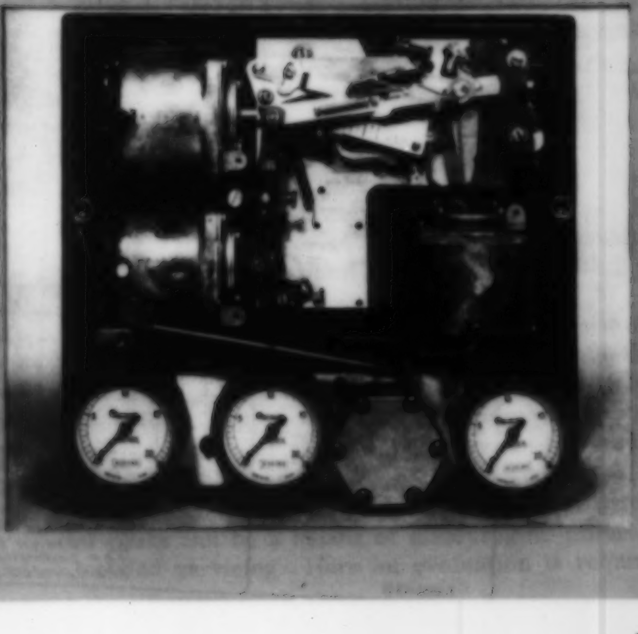
Tolerance to some inexperienced designers and engineers is a fudge factor added to dimensions on a drawing to keep methods engineers and inspectors happy. Yet this can be one of the most serious areas of trouble on any product and particularly on a new one. Proper dimensioning to minimize tolerance build-up in an assembly of parts is an art and requires the best co-ordination between the draftsman drawing the parts, the designer and project engineer who know where and how the parts are to be used, and the tool designer and methods engineer who are responsible for getting the part made correctly. Tolerance build-up due to improper dimensioning may, during the final assembly of a new product, prevent the most expensive parts in an assembly from going together.

Just imagine what can happen and what the cost could be to correct the situation—new tooling, costly rework, scrappage, production delays. Not only does cost enter the picture but product per-

Tooling cost for a low-volume component was reduced by redesign of a mercury switch bracket. Complicated tooling was required to produce the many bends in the original bracket (a). Additionally, two widely spaced holes had to be line reamed. Redesigned bracket (b) requires only one bend and eliminates need for line reaming by using a staked-in bushing



Final model which is almost identical with production models, incorporates redesigned components and other improvements. Pilot valve has been removed from the center of the linkage assembly to improve adjustment accessibility. One manifold serves as a mounting for meters and pilot valve and also provides for external connections. Internal tubing lines are reduced to a minimum. Performance tests indicated mounting angle should be changed from vertical to horizontal

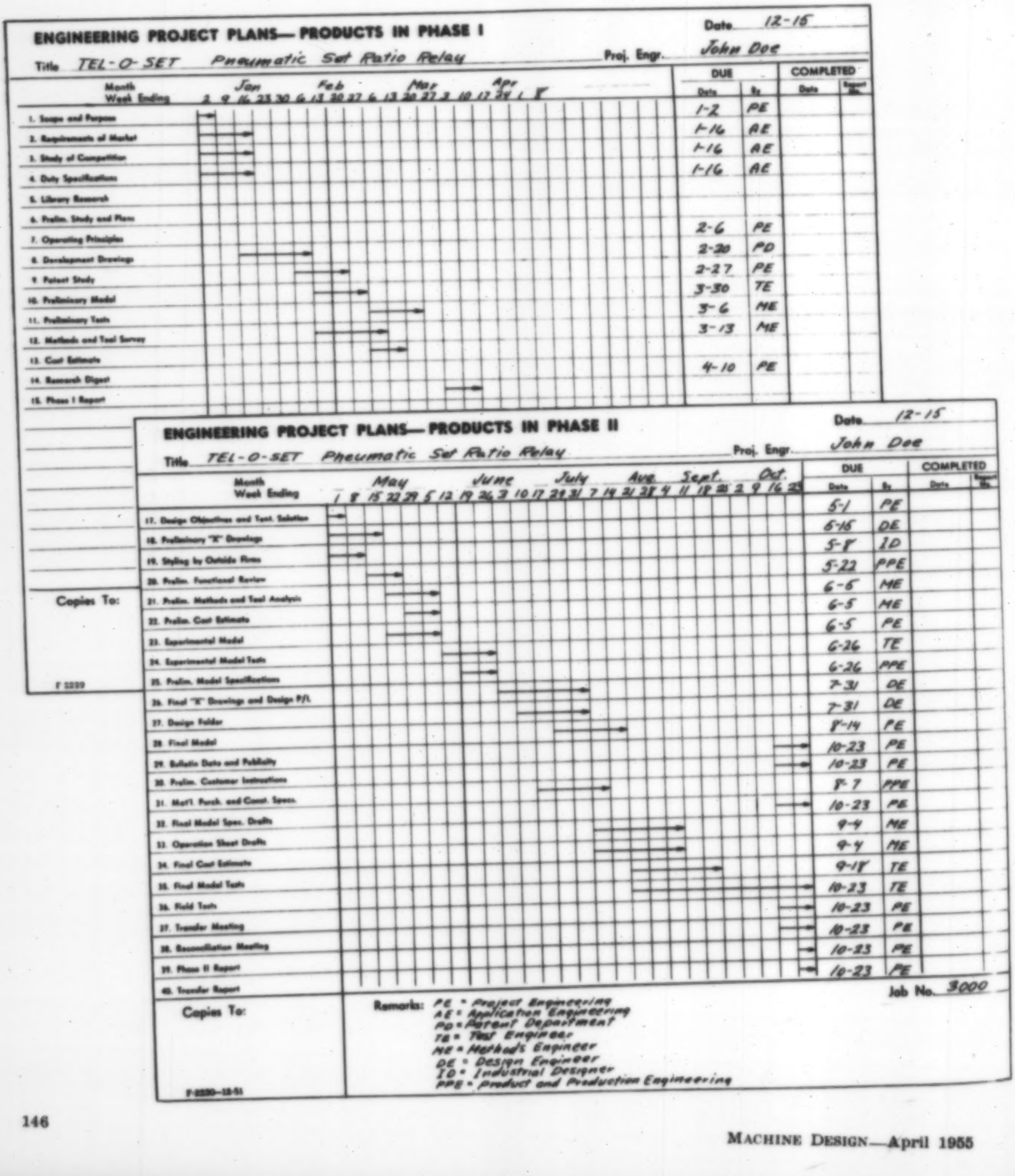


formance could be seriously impaired by improper tolerances.

Unfortunately, tolerance problems do not appear the first day production starts. As tools wear or parts from new tools mate with other parts from old tools the problems begin to multiply. Thus it becomes important that design dimensions and tolerances be carefully checked when all preliminary drawings are completed.

In a large organization where a designer has not become fully aware of production department layouts, handling, stocking, and operator and assemblymen's problems, designs of detail parts and assemblies can sometimes be improved to reduce problems that arise in these areas. Delicate parts which designwise and functionally may do the job, may not always arrive at the assembly station free from bends or damage. While this primarily is a handling problem, a design evaluation with

Fig. 2—A possible method for co-ordinating and timing the efforts of a design team is suggested by these project planning forms. Both time and responsibility are established. Steps outlined in the article are a general statement of the specific plan presented here



ENGINEERING PROJECT PLANS—PRODUCTS IN PHASE I

Date 12-15

Title TEL-O-SET Pneumatic Set Ratio Relay

Proj. Engr. John Doe

Month: Jan Feb Mar Apr

Week Ending: 2 9 16 23 30 6 13 20 27 6 13 20 27 3 10 17 24 1 8

	DUE Date	DUE By	COMPLETED Date	COMPLETED Report No.
1. Scope and Purpose	1-2	PE		
2. Requirements of Market	1-16	AE		
3. Study of Competition	1-16	AE		
4. Duty Specifications	1-16	AE		
5. Library Research				
6. Prelim. Study and Plans				
7. Operating Principles				
8. Development Drawings	2-6	PE		
9. Patent Study	2-20	PD		
10. Preliminary Model	2-27	PE		
11. Preliminary Tests	3-30	TE		
12. Methods and Tool Survey	3-6	ME		
13. Cost Estimate	3-13	ME		
14. Research Digest				
15. Phase I Report	4-10	PE		

Copies To:

F 2229

ENGINEERING PROJECT PLANS—PRODUCTS IN PHASE II

Date 12-15

Title TEL-O-SET Pheumatic Set Ratio Relay

Proj. Engr. John Doe

Month: May June July Aug. Sept. Oct.

Week Ending: 1 8 15 22 29 5 12 19 26 3 10 17 24 31 7 14 21 28 4 11 18 25 2 9 16 23

	DUE Date	DUE By	COMPLETED Date	COMPLETED Report No.
17. Design Objectives and Tent. Solution	5-1	PE		
18. Preliminary "X" Drawings	6-15	DE		
19. Styling by Outside Firms	5-8	ID		
20. Prelim. Functional Review	5-22	PPE		
21. Prelim. Methods and Tool Analysis	6-5	ME		
22. Prelim. Cost Estimate	6-5	ME		
23. Experimental Model	6-5	PE		
24. Experimental Model Tests	6-26	TE		
25. Prelim. Model Specifications	6-26	PPE		
26. Final "X" Drawings and Design P/L	7-31	DE		
27. Design Folder	7-31	DE		
28. Final Model	8-14	PE		
29. Bulletin Data and Publicity	10-23	PE		
30. Prelim. Customer Instructions	10-23	PE		
31. Mat'l. Purch. and Const. Specs.	8-7	PPE		
32. Final Model Spec. Drafts	10-23	PE		
33. Operation Sheet Drafts	9-4	ME		
34. Final Cost Estimate	9-4	ME		
35. Final Model Tests	9-18	TE		
36. Field Tests	10-23	TE		
37. Transfer Meeting	10-23	PE		
38. Reconciliation Meeting	10-23	PE		
39. Phase II Report	10-23	PE		
40. Transfer Report	10-23	PE		

Job No. 3000

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Remarks:
PE = Project Engineering
AE = Application Engineering
PD = Patent Department
TE = Test Engineer
ME = Methods Engineer
DE = Design Engineer
ID = Industrial Designer
PPE = Product and Production Engineering

F-2230-12-51

the intent of over-designing a part to strengthen it for interdepartment handling can eliminate costly prepacking, carrying trays, boxes, stockroom shelf space and defective parts scrappage. In addition overdesign or redesign can also reduce damage to parts as a result of an operator's lack of concern over the part as long as a piece rate can be met or surpassed.

Design evaluation of a group of parts is invaluable when it comes to making up subassemblies and assemblies. An understanding of production operations, pretesting, and stocking requirements is essential. The use of the lesser skilled operators where possible for assembly of subassemblies will reduce final product cost. In addition, the pretesting of as many parts and assemblies as possible before the final assembly will reduce if not eliminate part rejections, assembly tear downs and production delays. Establishment of these subassemblies for stocking purposes will also aid production control planning and will provide immediately available parts for service replacement by customers in the field as well as on the assembly line.

Servicing and maintenance: Another equally important objective of a design program is serviceability of the product. Need for this type of design evaluation may become all too apparent the day the product is packaged and shipped via flat-wheeled freight cars. A delicate assembly held together by luck and faith may never arrive at the customer's door as an assembly. Sensitive adjustments, improperly locked or without locking nuts or cotters, may no longer be in proper adjustment. Movable parts not tied down or restrained for shipment may not arrive in the same location as when shipped. For that matter they might well be lost among the wrapping paper and excelsior. The omission of shipping bolts, clamps and holes for tie-down may become serious in cases where a lack of careful handling during shipment exists. Careful evaluation of such problems will lead to a product that the customer will receive in good condition.

Customers and individuals who use and handle products are notoriously known as heavy-handed, large-thumbed, knob twisters. They are the individuals who read about the "don'ts" after the product has been returned for repair. Customer abuse is often overlooked in design until complaints are received. This is one more important factor to consider when evaluating a design.

Lack of strong handles, limit stops on lever systems, large size knobs, etc., can cause more trouble, service expense, and production delays for changeovers than the few minutes it takes to change the drawings during the design stage. Protrusions of delicate parts inadequately protected may be so damaged as to make the product perform improperly or not at all. While it is true that customer education can do wonders, the efforts involved might produce greater results when directed toward designer education.

Cycle life and life expectancy of parts become important factors in servicing. In some cases proper design is impossible due to space limitations or material. In other cases designing a part for 10 year's usage when its expected life will only be 30 seconds is impractical. In the former case the design should be evaluated to insure maximum possible life with the problem of servicing an important factor. In the latter case servicing is a somewhat minor, if not altogether nonexistent factor.

Accessibility of certain parts for adjustment by competent service and repair men must not be overlooked in making a design evaluation. Need for proper location of routine adjustments such as volume controls on radios, dashboard controls in automobiles, etc., is obvious. But the parts referred to here are those which must be accessible under the cabinets and engine hoods. Locating a carburetor adjustment between the radiator and fan in an automobile certainly wouldn't be the best location. Likewise the removal of a number of parts to reach an adjustment which affects the parts removed would not be acceptable either. Total absence of an adjustment can be a serious shortcoming which must also be considered during the design evaluation stage. Often the need for certain adjustments cannot always be determined during the design stage but careful evaluation based on past experience can be invaluable.

Accessibility of parts for removal and repair also is important. While a design program strives for perfection by eliminating troublesome parts and assemblies, past experience often indicates that certain parts will have to be removable for servicing. The location of screws, clamps, cotters, etc., as well as the part itself then becomes a vital consideration. If a part is known to be troublesome and a design correction appears impossible, then face the situation realistically and locate the part where it can be easily removed by disturbing as few other parts as possible. To aid in removing parts for servicing a clear distinction between fabrication screws and assembly screws can save many hours of embarrassing repair and reassembly operations.

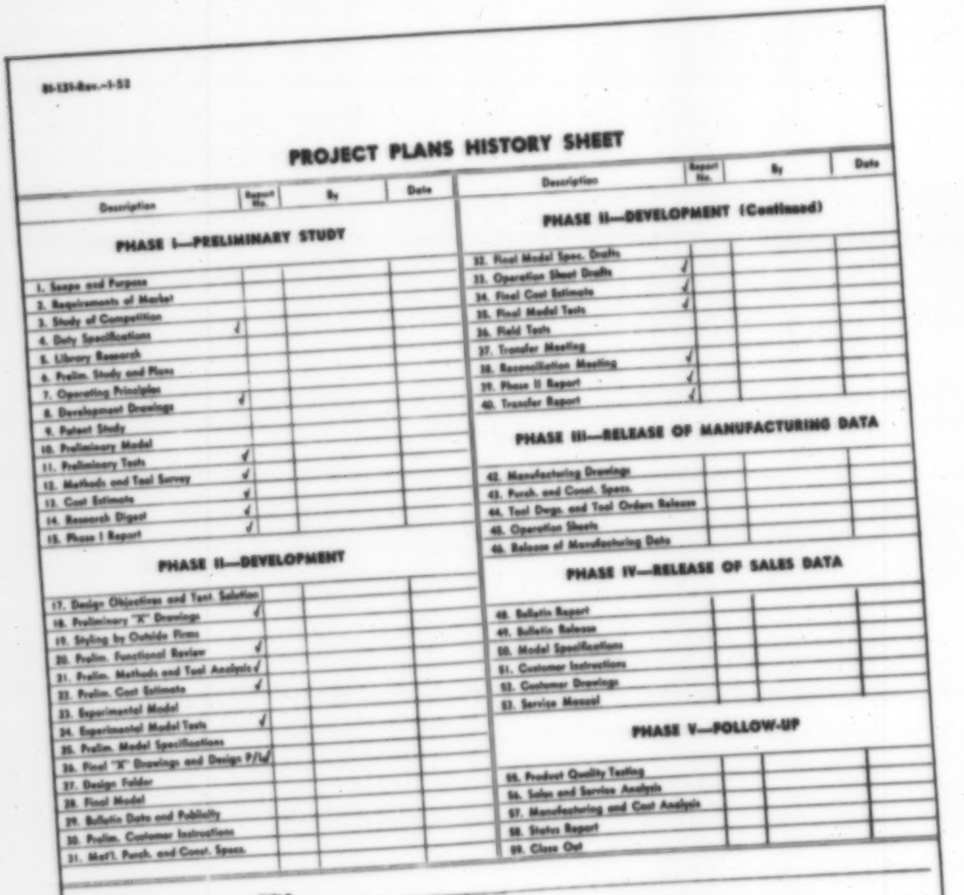
Special types of screws and clamps that must be frequently removed for servicing should be avoided to minimize the problems that develop if that part should be dropped or lost during repair work. Screws which are frequently loosened for removal of covers to get at adjustments should be captive to prevent their loss with the resulting inconvenience.

Use of special tools for assembling or servicing should be avoided also. In general the design should be evaluated, taking into consideration the type of customer who will be using the product and what type of tools he may have in his possession. In some cases the need for a special tool to make an adjustment or to disassemble a group of parts can be a means of discouraging unrecommended servicing. Here an evaluation is required not only of the design but also of the ultimate user of the product.

Production schedules: Final objective of a design program is to meet estimated production schedules and delivery dates. Proper design evaluation can reduce the number of corrective changes required once production has started. Making a corrective change once a production line has started can cause not only confusion but costly delays. Where large stock is involved the cost of scrapping or reworking this stock can be excessive, not to mention the extent of the trouble that will continue until new parts are available. These aspects of the problem can even be overshadowed by the months it takes to investigate a problem, find a solution, test the solution, change drawings, change tooling and make new parts. Sometimes these delays and costs can seriously handicap sales and the whole economic balance of a specific product as well as its associated equipment, parts, and services.

Organization: Need for proper design evaluation has been demonstrated. But it is the foresighted planning of a design program that best insures an effective evaluation. It becomes the responsibility of every individual assigned to the product's development to do his utmost to utilize his ability and experience to evaluate the design at specific planned stages. Every satisfactory product design program is the result of co-operative efforts from all individuals and departments. As in baseball, it is the well organized, smooth-operating team, using every individual's talents, that wins.

While the size of the team may vary among projects and manufacturers, an effective group is one that contains the equivalent of a project engineer, a design engineer, a methods engineer, a product and production engineer, a test engineer, and an application engineer. The responsibility of



BI-131-Rev.-1-53

PROJECT PLANS HISTORY SHEET

Description	Report No.	By	Date
PHASE I—PRELIMINARY STUDY			
1. Scope and Purpose			
2. Requirements of Market			
3. Study of Competition			
4. Duty Specifications ✓			
5. Library Research			
6. Prelim. Study and Plans			
7. Operating Principles			
8. Development Drawings ✓			
9. Patent Study			
10. Preliminary Model			
11. Preliminary Tests ✓			
12. Methods and Tool Survey ✓			
13. Cost Estimate ✓			
14. Research Digest ✓			
15. Phase I Report ✓			
PHASE II—DEVELOPMENT			
17. Design Objectives and Test Solution			
18. Preliminary "X" Drawings ✓			
19. Styling by Outside Firms			
20. Prelim. Functional Review ✓			
21. Prelim. Methods and Tool Analysis ✓			
22. Prelim. Cost Estimate ✓			
23. Experimental Model			
24. Experimental Model Tests ✓			
25. Prelim. Model Specifications			
26. Final "X" Drawings and Design P/L ✓			
27. Design Folder			
28. Final Model			
29. Bulletin Data and Publicity			
30. Prelim. Customer Instructions			
31. Mat'l. Purch. and Const. Specs.			

Description	Report No.	By	Date
PHASE II—DEVELOPMENT (Continued)			
32. Final Model Spec. Drafts			
33. Operation Sheet Drafts ✓			
34. Final Cost Estimate ✓			
35. Final Model Tests ✓			
36. Field Tests			
37. Transfer Meeting			
38. Reconciliation Meeting ✓			
39. Phase II Report ✓			
40. Transfer Report ✓			
PHASE III—RELEASE OF MANUFACTURING DATA			
42. Manufacturing Drawings			
43. Purch. and Const. Specs.			
44. Tool Dwgs. and Tool Orders Release			
45. Operation Sheets			
46. Release of Manufacturing Data			
PHASE IV—RELEASE OF SALES DATA			
48. Bulletin Report			
49. Bulletin Release			
50. Model Specifications			
51. Customer Instructions			
52. Customer Drawings			
53. Service Manual			
PHASE V—FOLLOW-UP			
55. Product Quality Testing			
56. Sales and Service Analysis			
57. Manufacturing and Cost Analysis			
58. Status Report			
59. Close Out			

JOB NO.__________ TITLE __________

EXPENSE ACCOUNTS: LABOR E—__________ MATERIAL E—__________

PROJECT ENGR. __________

PH. II AUTHORIZED __________ Mgr. of R & D or P & A Eng.

PH. III & IV AUTHORIZED __________ V. P. of Engineering

BULLETIN AUTHORIZED __________ Mgr. of P & A Engineering

TOOLING AUTHORIZED __________ V. P. of Engineering

PH. V AUTHORIZED __________ Mgr. of P. & A. Engineering

DATE JOB OPENED __________

ENGINEERING HOURS __________

MODEL LABOR $__________

MATERIAL $__________

DATE JOB CLOSED __________

Fig. 3 — This form shows the complete series of steps in a typical product development program. Checked steps are those at which design evaluation logically occurs

each must be clearly defined and the design evaluation by each must be effectively timed.

The project engineer directs the whole project from the initial layout stage to the initial production run. He must be responsible for evaluating and incorporating all changes recommended by the rest of the team and must insure that each individual's efforts and evaluations are performed on schedule. Above all he must be certain that basic objectives of the design program are met.

The design engineer makes the layouts and details. He is responsible for the designing of all the parts that go to make up the product. He must be responsible for all design data and calculations and the adherence to standard design practice.

The methods engineer is responsible for tool analysis and parts processing. He must insure that the parts can be made as designed using the equipment and methods available. He must make a design evaluation with recommendations based on manufacturing costs which will keep tool, parts, and assembly costs to a minimum. He must be responsible for establishing the cost estimates of all parts and assemblies.

The product and production engineer is responsible for a detailed design evaluation that insures that from all aspects the four basic objectives of the design program are being satisfied by the product design. Primarily he must see that the design utilizes standard, tried and proved economical parts, that it is serviceable, that it is functionally satisfactory, and that adequate subassembly and assembly parts are made that will insure proper pretesting and stocking of parts for satisfactory production operations. He must establish the necessary testing, calibration, and inspection procedures. In addition he must perform a competitive evaluation, an economic evaluation, and a design evaluation that insures that the best design possible is being developed.

The test engineer is responsible for an adequate testing program that will evaluate whether or not the product meets with design and performance specifications. By performing the evaluation as both a potential inspector and customer he can insure a satisfactory design.

The application engineer is responsible for establishing the initial design and performance specifications based on his experience and understanding of the customer's and sales' needs. He must insure that the product has the features which will make the product meet with customer acceptance, and he must obtain and evaluate the reactions of customers and salesmen to the product. He must keep up with the ever-changing field requirements to insure that the newest and latest desired features are included in the design of the product.

By effectively combining and properly timing the evaluations by these individuals, *Fig.* 2, management can be assured that a satisfactory product is being designed that will meet the four basic objectives of the design program.

Project planning: Most project planning should follow a pattern. The complexity and number of steps, of course, would depend upon the size of the project. But in general it should follow a step-by-step procedure such as:

a. Design and performance specifications
b. Development layouts and sketches
c. Preliminary functional testing
d. Preliminary, design, methods, and performance evaluation
e. Preliminary experimental drawings
f. Experimental testing
g. Experimental methods, tool, and cost evaluation
h. Experimental design and performance evaluation
i. Final drawings
j. Final testing
k. Final methods, tool and cost evaluation
l. Final design and performance evaluation
m. Design frozen for production
n. Production drawings, tooling, and processing

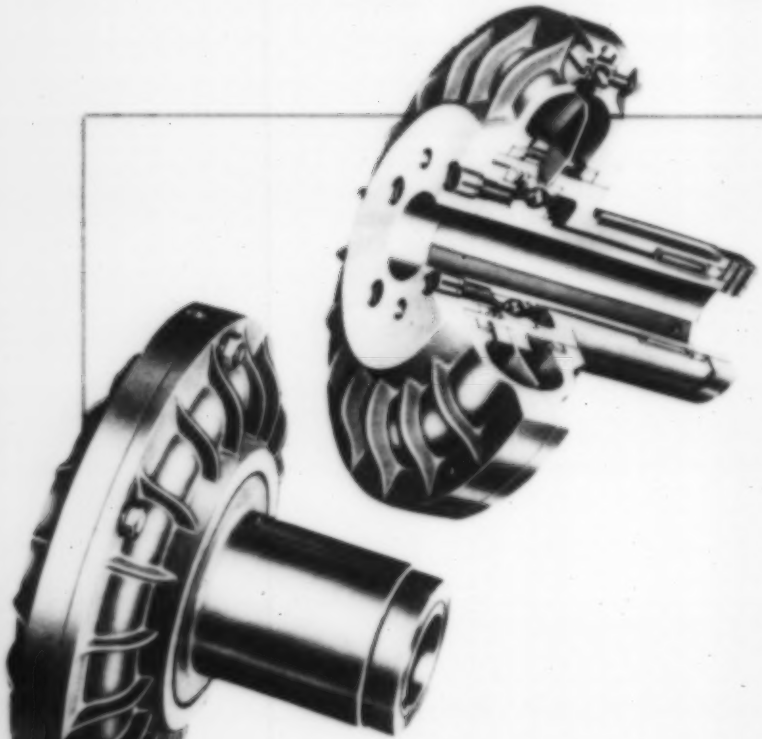
There are obviously other steps between the ones indicated, *Fig.* 3, but by and large the various evaluations required should be performed by the specific individuals assigned to the design program, at the planned stages indicated. In general before each stage of drawing work is started there should be a group discussion in which all recommended changes are evaluated and the direction of the next stage outlined. In that way all individuals concerned are up to date on the progress of the job and know what lies ahead.

They Say . . .

". . . the importance of product design to good automation is not yet fully realized. The designers of parts must be thoroughly educated in the ways automation operates. The designer who is familiar with automation and designs his product with automated production in mind can make the work of master mechanics easier and can save his company thousands and even millions of dollars. The simple precaution of designing a flange that turns out instead of in on an automobile body can make the difference between a manual and an automated operation on the production line. Although turnovers and rotations can be accomplished by the use of mechanical production aids, the designer who can eliminate them will simplify production problems and reduce costs."—WILLIAM NEWBERG, *vice president, Chrysler Corp.*

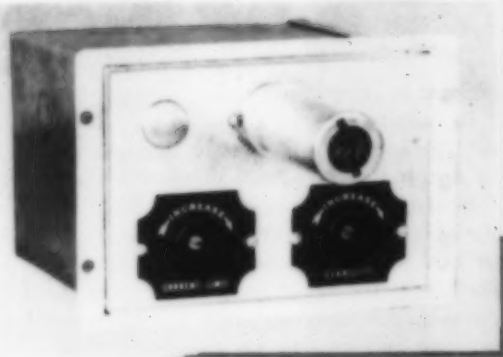
CORRECTION: In the article "How Rotation Affects Hydraulic Pressures" (February, 1955), the illustrations identified as *Figs.* 11 and 12, Page 184, were transposed. On Page 182 the second sentence following Equation 7 should read "Since the units of *W* in Equation 7 are pounds per cubic inch . . . ." Our thanks to Howell C. Lowe of Electrol Inc. for bringing these to our attention.

SCANNING the field for IDEAS



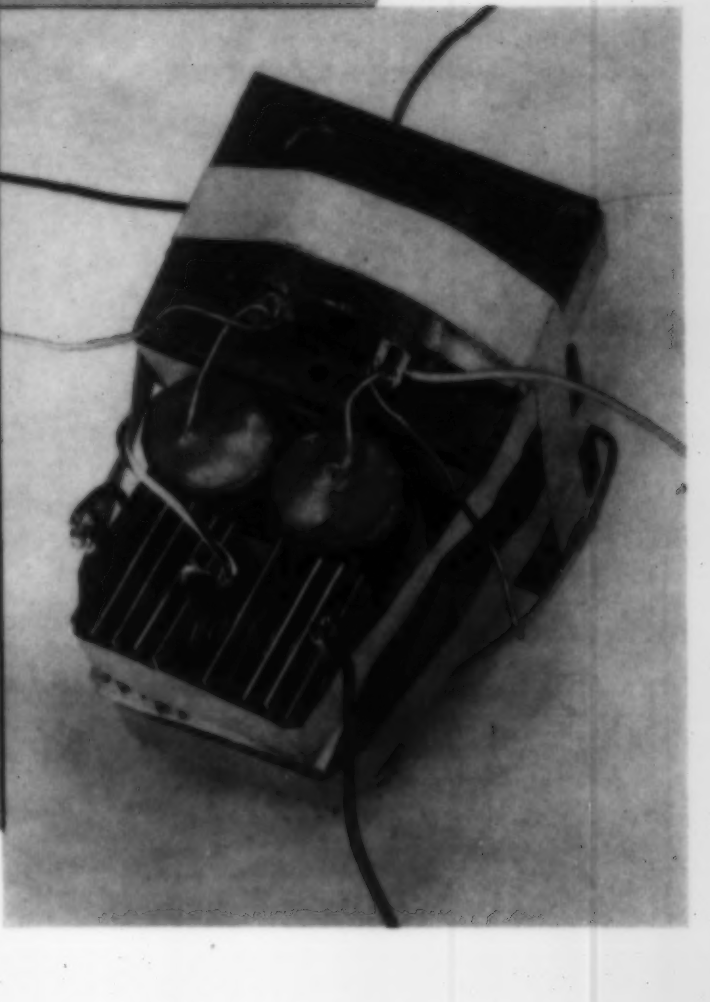
"DRY FLUID" DRIVE is designed not to slip at normal operating speed and load. The functioning of the transmission depends on the laws of friction and centrifugal force. Although the drive idea originated in Europe and has been widely applied there, this unit has been redesigned by the Dodge Mfg. Corp. to American standards and tradenamed Flexidyne.

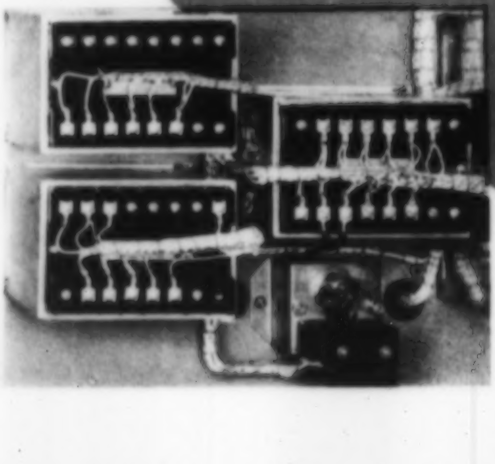
Basically the drive consists of a housing inside which a rotor is free to turn concentrically. Between the two is a "flow charge" which transmits power from the housing to the rotor. The flow charge acts much like a fluid and is composed of small spherical steel shot. In application the power-source shaft is connected to the housing, and the rotor to the load. When the input shaft starts to rotate, there is practically no load. Therefore the drive housing quickly accelerates; the flow charge is thrown to the housing circumference, is compressed by centrifugal force, and revolves with the housing. The rotor, connected to the load, is started and accelerated by the friction and wedging action of the revolving flow charge aided by the wavy contour of the rotor blade. Soon the rotor and housing operate at identical speeds or zero slippage. Before any damage can occur in case of an overload, the rotor slips relative to the housing by overcoming the friction and wedging action of the flow charge. Overload protection can be set to slip anywhere from 20 per cent over full load torque to as high as peak motor torque. The torque capacity of the unit is determined by the amount of flow charge.



PACKAGED SEALED CIRCUITS are used as electronic building blocks in Reliance Electric adjustable-speed drive systems. Electronic components of complete individual circuits are permanently encased in plastic except for tubes and potentiometer adjusting shafts. The plastic not only provides firm support for the electronic parts, but also isolates them from unfavorable environmental conditions such as moisture, dust, dirt, corrosive atmospheres, etc. Delicate components are claimed to be better protected from vibration by this circuit packaging method. Also, heat is said to be conducted away from heat-producing components faster through the plastic than it would through still air.

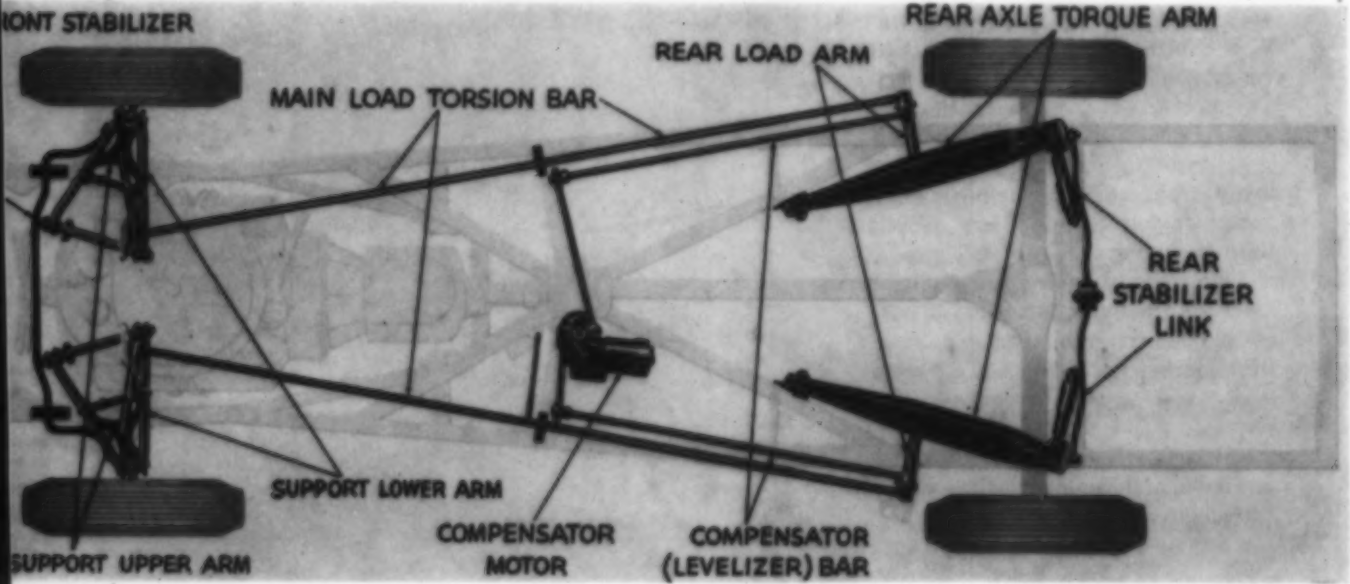
Electronic maintenance problems are simplified and downtime in case of trouble is minimized. A malfunctioning unit can be removed easily and quickly by simply disconnecting wiring leads on a terminal strip in back and four screws in front, and replaced with a new sealed circuit.

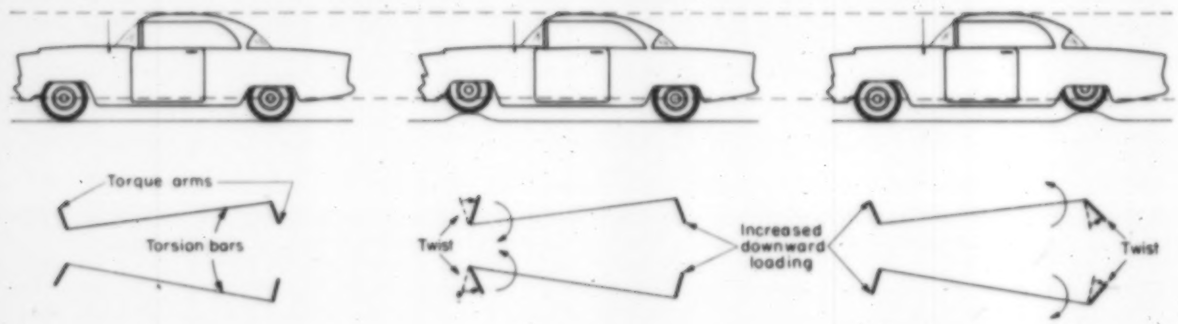




TORSION BAR SUSPENSION available in 1955 Packard and Clipper lines markedly improves car riding quality and ride control. Two straight manganese-steel bars approximately 9 feet long and nearly 1 inch in diameter are used in place of coil or leaf-spring suspension systems. These bars run on each side of the chassis frame from front to rear, connecting the front and rear wheels through arms and links. Fastened at each end of the bars and pointing in opposite directions with respect to each other are arms which twist the bars when the wheels suddenly drop and rise traveling over rough terrain. For example, if a bump deflects the front wheels upward, the resulting twist in the torsion bars increases the downward loading in the rear torque arms while the chassis and body tend to remain relatively in the same level. The reverse motion would occur when the rear wheels struck the bump. Most of the shock caused by a rapid change in wheel elevation bypasses the car body since much of the impact energy is expended in twisting the torsion bar which passes the reaction through the wheel at the opposite end to the road.

In order to assure constant car riding level for any load, Packard has combined the torsion bar with an automatic leveling system or compensator. The function of the compensator is to hold body height on an even keel regardless of passenger and luggage loads. Included in the leveling system are two short torsion bars about 4 feet long which are also fastened to the rear load arms at one end and to an actuator lever and compensator gear box at the other end. A reversible dc motor on the gear box automatically levels the car body by twisting the compensator torsion bars in the proper direction and amount. Motor rotation direction and operating duration are controlled by switch connected to a lever rigidly attached to the left main torsion bar. A 6-second time delay prevents the leveler from working when the car hits a bump. Also, a special switch on the brake pedal opens the circuit to the actuator motor to prevent operation during a braking period. In addition, a "flat-tire switch" under the dash can be used to cut out the leveler when jacking up the car.

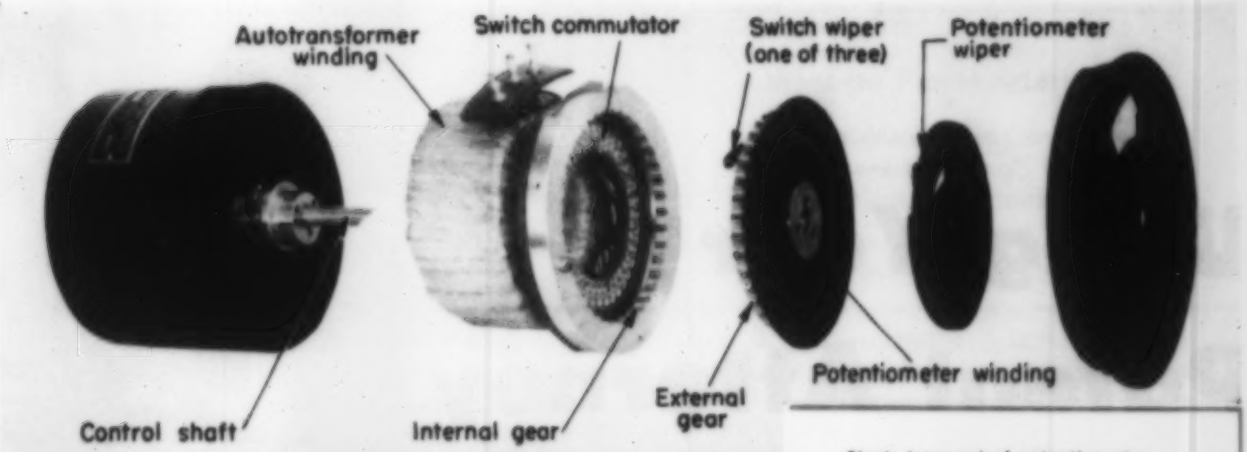




Normal Position

Front Wheels Deflected up

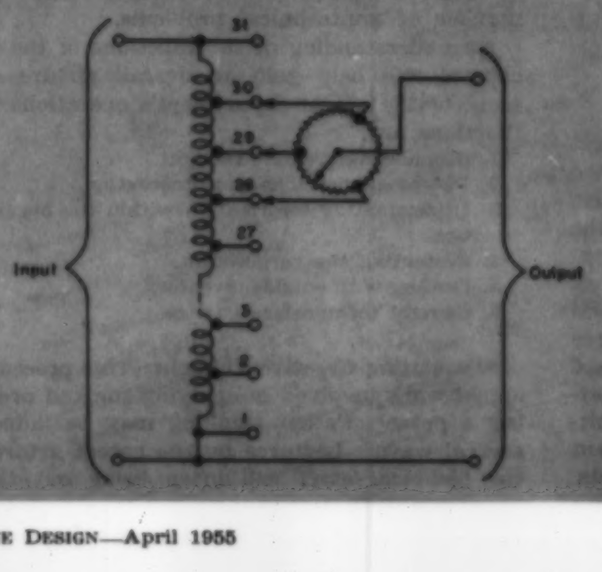
Rear Wheels Deflected up

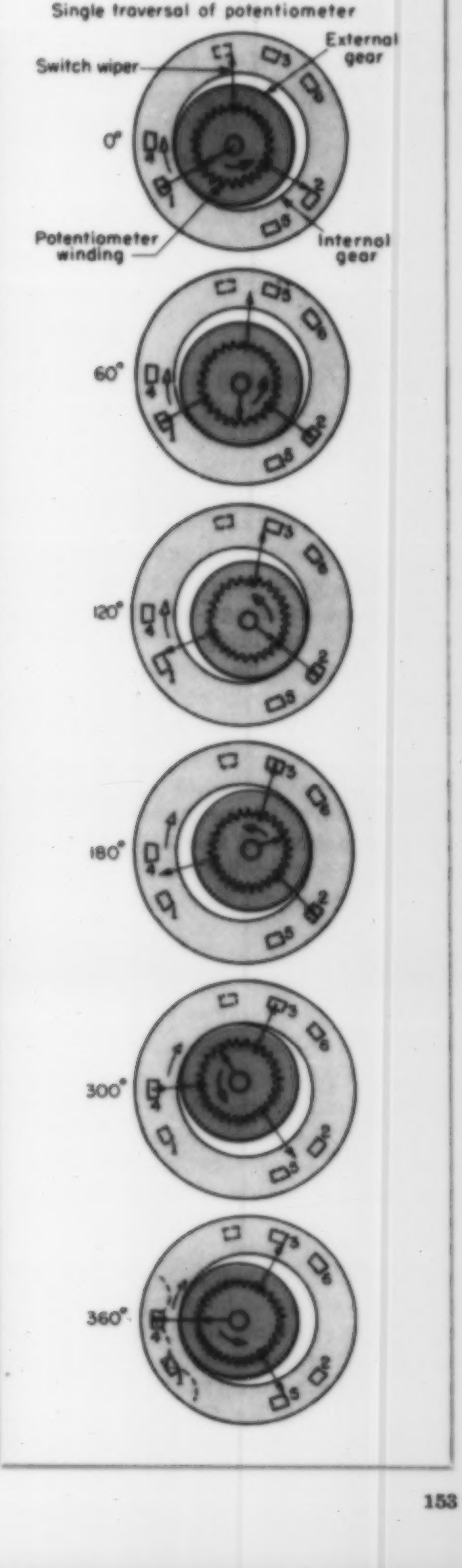

Autotransformer winding
Switch commutator
Switch wiper (one of three)
Potentiometer wiper
Potentiometer winding
External gear
Control shaft
Internal gear

AUTOTRANSFORMER AND POTENTIOMETER team up in the design of a precision voltage divider developed by the Vernistat division of Perkin-Elmer Corp. This unique mechanical-to-electrical transducer has the low output impedance characteristic of variable autotransformers. At the same time the unit also exhibits the high resolution and linearity of output associated with multiturn potentiometers.

The device is designed around a tapped autotransformer which provides several discrete levels of voltage. Leads from 31 taps on the autotransformer are connected to various segments of a switch commutator. Attached to the potentiometer assembly are three switch wipers, located 120 degrees apart, which rub the switch commutator, and these are electrically connected to three taps on the potentiometer winding. Voltage output of the transducer is smoothly varied by rotation of the control shaft; this movement causes the continuous one-turn potentiometer to be sequentially connected to sections of the autotransformer in synchronism with the potentiometer wiper arm rotation.

The potentiometer assembly is supported on an eccentric section of the control shaft and is mechanically connected by an external gear to an internal gear on the switch commutator assembly. The external gear has one tooth less than the internal gear which allows the potentiometer assembly to progress a distance of one tooth along the internal gear per revolution. One traversal of the potentiometer advances the switch wipers through three autotransformer voltage steps.


31
30
29
28
27
3
2
1
Input
Output


Single traversal of potentiometer
Switch wiper
External gear
0°
Potentiometer winding
Internal gear
60°
120°
180°
300°
360°
1
2
3
4
5
6

Using Your Patent Attorney

How design and technical personnel can make full use of a patent attorney's skills

By Reuben Wolk, *Patent Attorney, Purolator Products Inc., Rahway, N. J.*

DESIGN engineers and technical personnel may find their company patent attorney an invaluable aid in many phases of creative work. Background and training prepare a patent attorney to be of service to the technical staff by stimulating ideas, preparing patent applications, disseminating technical information, and helping write papers and articles.

His broad coverage of the technical field may help the designer bring out new considerations that might otherwise be overlooked. Time lost on a useless or previously solved design problem could be eliminated with his guidance.

Besides being of assistance to his company's engineers, he may help the company in other ways. In these days of complex industrial operations, there are a host of specialized problems. Some of these are contract licensing, copyright and trademarks, publications, advertising and patent protection. Expert advice and consideration are needed at every step.

Careful consideration of the attorney's usefulness should be preceded by an examination of his background and training.

Background of the Patent Attorney: In almost every case, the patent attorney has a degree in a science such as engineering, physics, or chemistry, and a degree in law. He usually has passed the bar examination of a state or the District of Columbia, and is admitted to practice before the U. S. Patent Office. This latter admission is accomplished by virtue of his having spent at least three years as an examiner in the Office or having passed a special examination to show his knowledge of patent practice. In addition, he will usually be admitted to the bar of the Court of Customs and Patent Appeals, the favorite appeal court of most litigants.

The patent attorney has spent many years searching the records of old patents, thus building up his technical background in dozens of fields. He often has written thousands of words on technical and legal matters. He has analyzed, objected, agreed and persuaded.

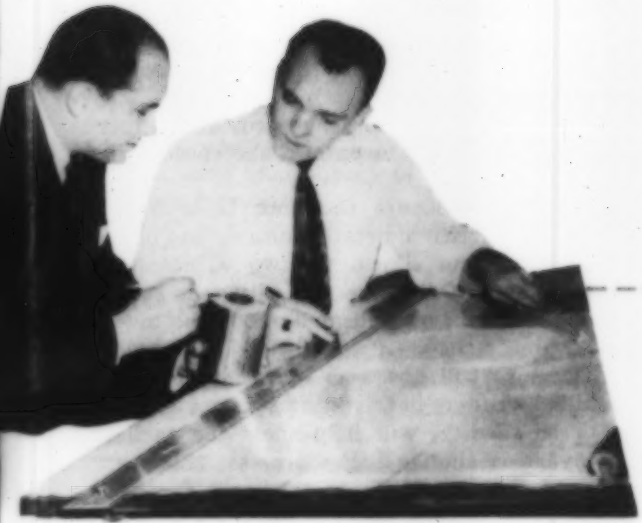
This varied background brings a combination of qualifications that can be utilized fully for the complex problems faced by the modern corporation.

Functions of the Patent Attorney: By working closely with technical employees to suggest designs and stimulate thinking, he can make every designer, test engineer and mechanic a potential inventor. Because of the necessity of close co-operation with other employees, the attorney is usually responsible either to the head of the engineering department or to the president of the company. This depends upon whether his work is all technical, or whether it includes a considerable number of nontechnical problems.

An understanding of the functions of the patent counsel will help gain an overall picture of the scope of the patent department's operations. These functions are:

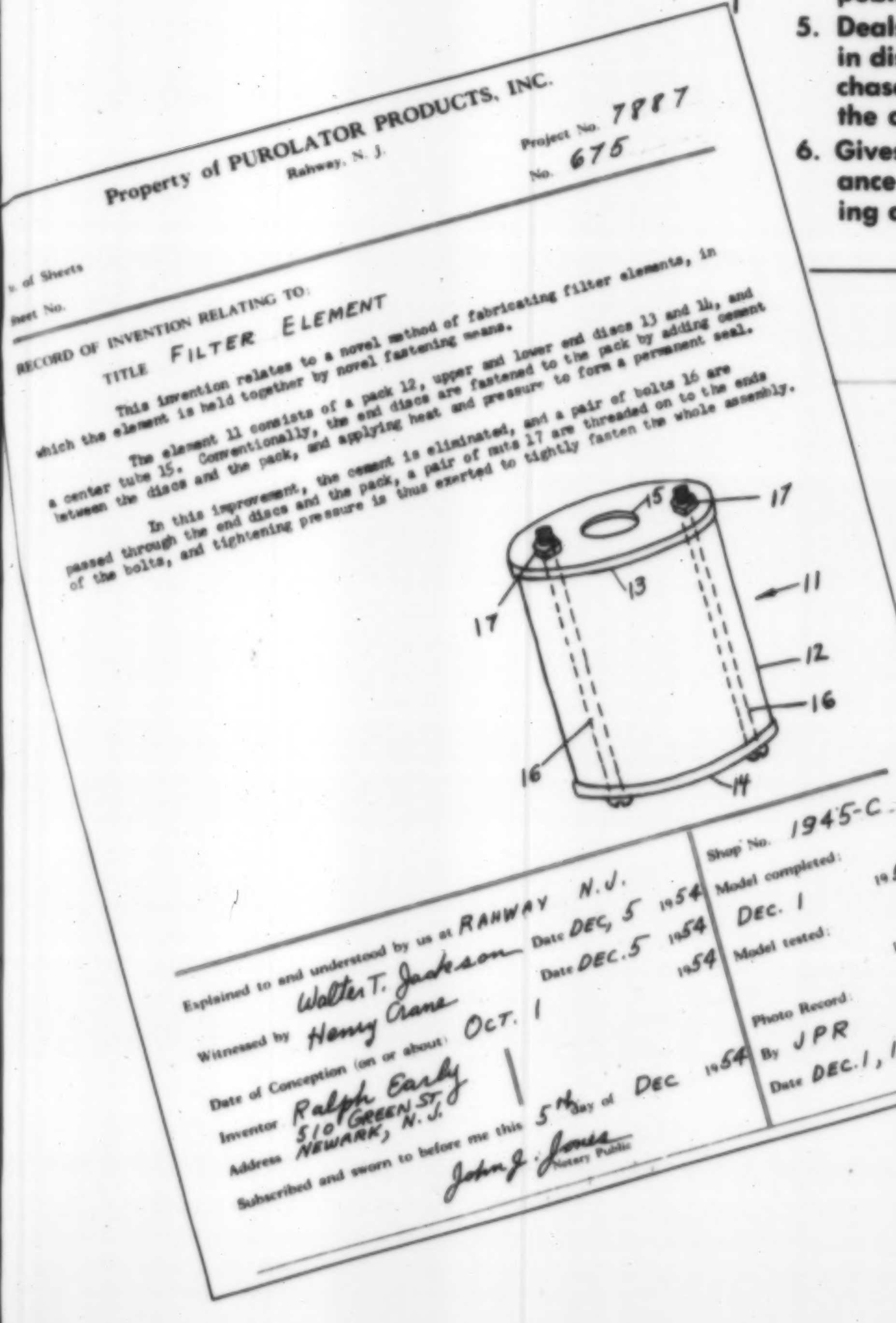
1. Stimulating creative thought.
2. Patent applications and prosecution.
3. Disseminating information within the organization.
4. Protecting the corporation.
5. Dealing with outside inventors.
6. General technical assistance.

Stimulating Creative Thought: This precedes the actual work involved in applying for and prosecuting a patent. Patent thinking may be induced in several ways. Lectures by the patent attorney to the technical staff will often bring out the de-



What the Patent Attorney Does

1. Stimulates ideas by inducing "patent thinking" among the technical personnel.
2. Writes disclosures, patent applications and prosecutes patents.
3. Disseminates information throughout the organization regarding patent and other technical matters.
4. Protects the corporation by watching for patent and trademark infringement, handles contract and licensing matters, checks speeches and publications.
5. Deals with outside inventors in discussing the possible purchase of their inventions by the company.
6. Gives general technical assistance by helping with the writing of articles and papers.



Property of PUROLATOR PRODUCTS, INC.
Rahway, N. J.

Project No. 7887
No. 675

of Sheets
Sheet No.

RECORD OF INVENTION RELATING TO:
TITLE FILTER ELEMENT

This invention relates to a novel method of fabricating filter elements, in which the element is held together by novel fastening means.

The element 11 consists of a pack 12, upper and lower end discs 13 and 14, and a center tube 15. Conventionally, the end discs are fastened to the pack by adding cement between the discs and the pack, and applying heat and pressure to form a permanent seal.

In this improvement, the cement is eliminated, and a pair of bolts 16 are passed through the end discs and the pack, a pair of nuts 17 are threaded on to the ends of the bolts, and tightening pressure is thus exerted to tightly fasten the whole assembly.

Explained to and understood by us at RAHWAY N.J.
Walter T. Jackson Date DEC, 5 1954
Witnessed by Henry Crane Date DEC. 5 1954
Date of Conception (on or about: OCT. 1 1954
Inventor Ralph Early
Address 510 GREEN ST. NEWARK, N.J.
Subscribed and sworn to before me this 5th day of DEC 1954
John J. Jones Notary Public

Shop No. 1945-C
Model completed: DEC. 1 1954
Model tested: 19
Photo Record:
By JPR
Date DEC. 1, 1954

Fig. 1 — A typical printed disclosure form that may be filled in and signed by the inventor and witnesses. A disclosure properly executed will help establish the earliest date of invention

signer's latent thoughts. Another method is to assign new engineers to work with the attorney for a few days as part of their training program.

By working with design engineers to encourage thinking along patent lines, the attorney may often release a flood of new ideas. Among these many ideas may be at least one worth developing to the point of a patent application.

Patent Application and Prosecution: Most of the the attorney's day-to-day work is the preparation of disclosures, applications and litigation with the Patent Office. Here, the designer with an idea comes into personal contact with the patent operation. This phase is of most concern and interest to the would-be inventor.

Most potential patents usually come from engineering or laboratory personnel. When one of these employees has designed a new part, a new process, or a new machine, the patent attorney should be consulted regarding patent possibilities.

During the consultation, the designer will explain his idea in detail. He should be armed with laboratory notes, sketches, engineering drawings or photographs. At this time, the patent attorney will fill out a disclosure form, *Fig.* 1. He may sketch the invention in the space provided or perhaps simply attach the inventor's sketches to the form.

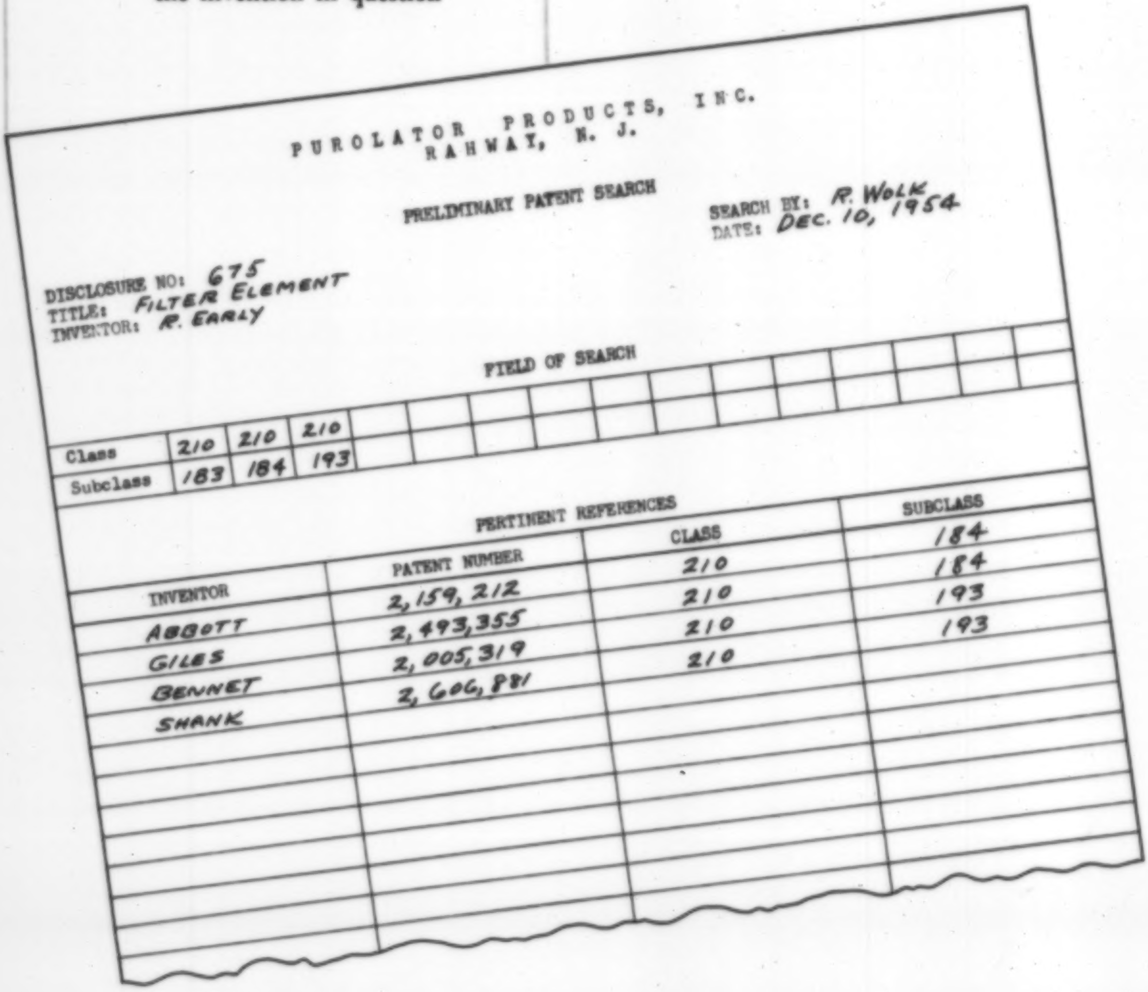
Actually, the disclosure need not be a formal printed blank. A written, detailed description of the invention, dated and signed by two witnesses is usually sufficient. Of course, the witnesses should have read the disclosure and understood the invention.

The disclosure will now serve as the basis of a more detailed write-up in the event a patent application is to be filed. It will help show the earliest date of invention should litigaton arise. This form does not, of course, eliminate the need for data sheets, design drawings, laboratory notebooks or other evidences of invention. These records are highly important.

After the disclosure is filed, the idea is usually searched in the files of the Patent Office. A record of the field of search and the pertinent references should be made. A form, *Fig.* 2, may be used for this purpose and then kept on file.

Periodic discussions of all such ideas and results of searches are held with the head of the engineering department or with a committee. Each idea is

Fig. 2—One suggested way of keeping a record of the results of patent searches. References show any existing patents that may be pertinent to the invention in question



PUROLATOR PRODUCTS, INC.
RAHWAY, N. J.

PRELIMINARY PATENT SEARCH

SEARCH BY: R. WOLK
DATE: DEC. 10, 1954

DISCLOSURE NO: 675
TITLE: FILTER ELEMENT
INVENTOR: R. EARLY

FIELD OF SEARCH

Class	210	210	210
Subclass	183	184	193

PERTINENT REFERENCES

INVENTOR	PATENT NUMBER	CLASS	SUBCLASS
ABBOTT	2,159,212	210	184
GILES	2,493,355	210	184
BENNET	2,005,319	210	193
SHANK	2,606,881	210	193

evaluated as to its patent possibilities and its subsequent value to the company. Patent applications are written for those inventions deemed acceptable.

A patent application consists of four major parts:

1. A carefully written, detailed description of the idea, such that anyone in the field who reads it can duplicate it.
2. A set of claims, which define the scope of the invention.
3. A set of drawings.
4. The inventor's oath.

After the application is completed and executed, an assignment from the inventor to the company is added, and the papers are filed with the Patent Office.

During the course of the next few years, a series of rejections and amendments are usually exchanged between the Patent Office and the attorney. The latter will be prepared to show how the application differs from the references cited, and call on all his technical and legal knowledge to reinforce his arguments. In particularly stubborn or important cases he will plan on personal interviews with the examiner in Washington. He may even be called upon to bring a model of the invention. After all this, if the invention has merit, the patent should issue.

While the heart of the patent attorney's daily activity deals with patent litigation, his background and training make him useful to his company in many other ways.

Disseminating Information: One important function of the patent man is the dissemination of information within the organization. He keeps abreast of the current patent situation by a perusal of the weekly Gazette issued by the Patent Office and such publications as the Commissioner's Decisions on patent litigation. He not only keeps himself informed, but acquaints technical personnel with new developments by competitors. This information may often stimulate efforts along the same lines.

Another facet of informaton dissemination is the reporting of progress of applications. All those interested, starting with the inventor, and passing on to the head of engineering, the accounting department and the company president are usually informed of the status of the application.

The patent attorney can serve on an employees' suggestion committee. This places him in a perfect position to analyze suggestions for any patent coverage. At the same time he can place his knowledge and talents at the disposal of the committee.

Protection of the Corporation: Just as any attorney must protect his client, the Patent Attorney will exercise all his skill to protect the corporation. For example, it should be his job to draw up a suitable form for execution by each technical employee which grants rights to the company in the event of inventions by that employee.

Another form of protection involves expiration of the corporation's patents. A patent is issued for a period of 17 years, after which it is public property. In this connection, the patent man will notify technical personnel of the impending expiration. He will try to stimulate thought along the lines of improvement of the expiring patents so that steps can be taken toward obtaining an even more effective one.

Trademark and copyright problems also fall within the scope of the attorney's functions. He acts as a policeman, not only in watching for publication of trademarks and copyrighted articles by other companies, but in watching his own corporation's news releases, advertising, public speeches and packaging.

Ordinarily he handles all the legal details involving license agreements between his corporation and others. Generally he will review or even draw up contracts between his company and others.

Dealing with Outside Inventors: Often outsiders approach the corporation with inventions or bright ideas in the hope of effecting a sale. Many designers, finding their own employer cannot use their invention, often approach other companies who might be interested in their idea.

Special handling of these cases is required by the patent attorney. Usually the outsider is required to sign a form relieving the company of any liability or responsibility arising from the presentation of the invention to the company's patent attorney. Some companies take the easy way out by refusing to look at an invention unless the inventor has already filed an application for a patent.

General Technical Assistance: Because of his varied training and background, the patent attorney may be called upon to solve many general technical problems. For example, his training in writing patent specifications may be useful in assisting the writing of technical material for magazines. Service manuals and instruction books are often written with the patent attorney's assistance. He may even be called upon to handle technical education classes.

Conclusion: Designers may well profit by a knowledge of their patent attorney's functions. The attorney can usually supply them with technical information not usually available through regular technical channels. He may help guide them in creative thinking by supplying data and information of previous inventions in the same field.

Many smaller corporations who do not have their resident attorney may also find they can economically justify his place on their payroll. Because of his combined talents, he often is able to step into a gap created by a lack of personnel having particular qualifications. By devoting his full time to one corporation, he may be profitably utilized in many ways besides patent litigation.

Multiple-Circuit Switches

Selection and Application

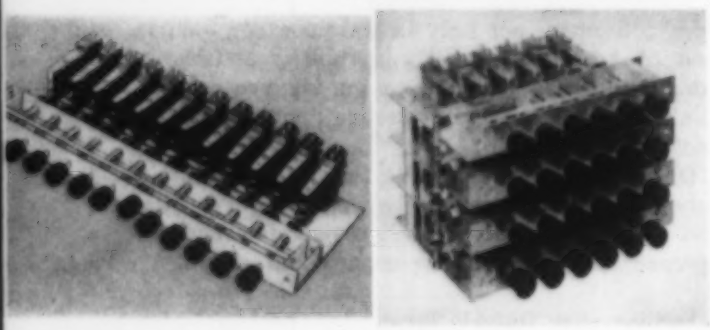
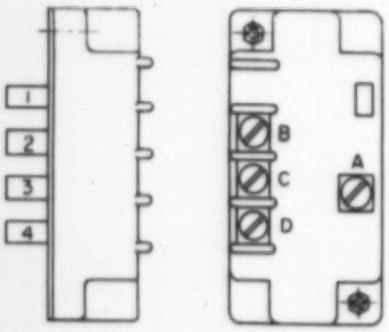


Fig. 1 — A 12-button multiple-pushbutton leaf-spring switch and a 24-button, four-row switch of the same type illustrate the multiplicity of switching arrangements possible

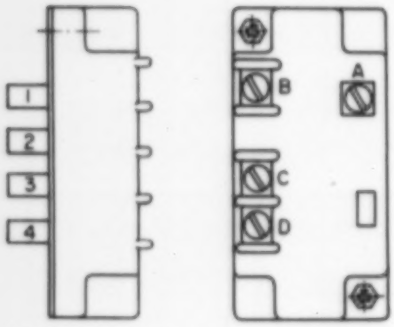
COMPARATIVE ease of operation is one of the prime attributes of the push or pull group of switches. Motion required of the operator for switch operation is both natural and simple. Current ratings of these switches range from a few milliamperes for the small "radio" types to 60 amperes for large, heavy-duty units. Maximum voltage ratings are 600 volts. Although these current and voltage ratings do not cover as great a range as the rotary switches, push and pull type switches can be used in many machine control applications.

Push and pull type switches may be divided into six groups. Switches within each of the first five

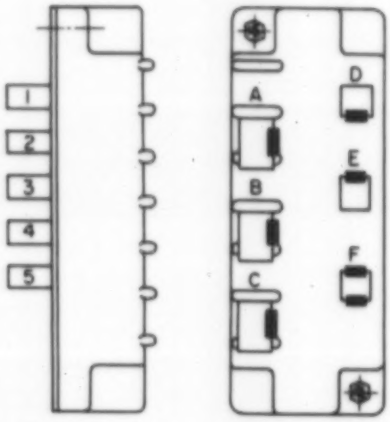
Fig. 2—Sliding-cam switches offer a variety of possible switching setups



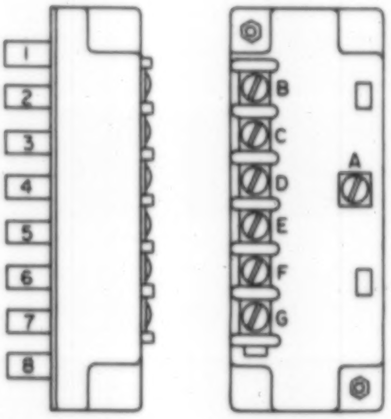
Button Pushed	Connections Made
1	None
2	A to D
3	A to D, B
4	A to D, C



Button Pushed	Connections Made
1	None
2	A to B & D
3	A to B, C & D
4	A to C & D



Button Pushed	Connections Made
1	None
2	A to D, B to F, C to E
3	A to C & D, B to F
4	A to D, C to F, B to E
5	A to B & E, C to F



Button Pushed	Connections Made
1	None
2	A to D & F
3	A to B, D & F
4	A to E & G
5	A to D & G
6	A to C & F
7	A to B & F
8	A to B & G

By
Keith A. Carlson
Assistant Editor
Machine Design

# of Push or Pull Switches

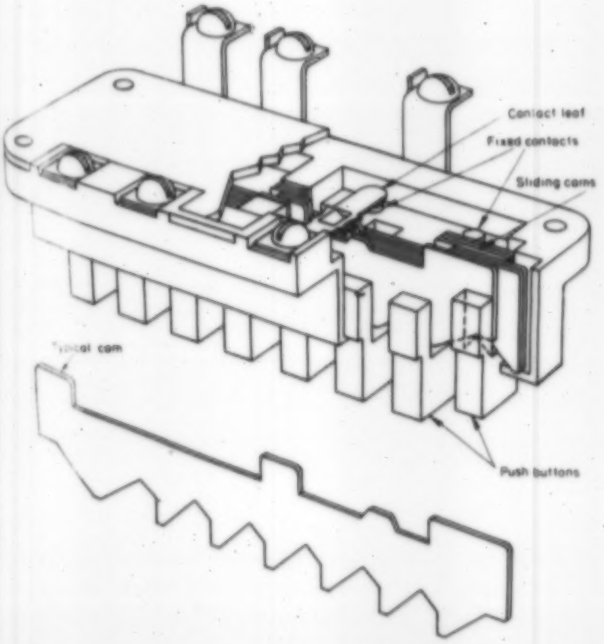
Manually operated, multiple-circuit switches are of three primary types —(1) lever, (2) rotary, and (3) push or pull-operated switches. Physical and electrical characteristics of lever and rotary types have been discussed in two previous parts of this series of articles. (MACHINE DESIGN, October, 1954, Page 154, and January, 1955, Page 183). This article covers physical and electrical characteristics of the push and pull-operated types. Factors to be considered in choosing switches of these types will be the subject of the final article in the series.

groups bear strong resemblances to each other, although products of different manufacturers may differ in detail. The six types are:

1. Push-operated leaf-spring switches.
2. Sliding-cam multiple pushbutton switches.
3. Miniature snap-action push switches.
4. Sliding contact push or pull switches.
5. Industrial pushbutton switches.
6. Miscellaneous types.

Push-Operated Leaf-Spring Switches: Pushbutton switches of the leaf-spring type are made up of the same standard leaf spring buildups described in the previous article on lever-operated switches

Fig. 3—A group of sliding cams cause contacts to be made or broken as the various buttons are pressed on sliding-cam switches



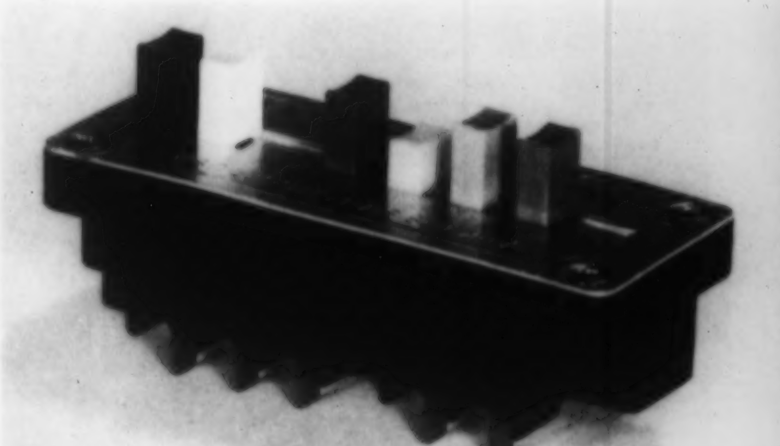


Fig. 4—This switch assembly has two separate groups of buttons which operate independently of each other. Buttons are available in a variety of colors

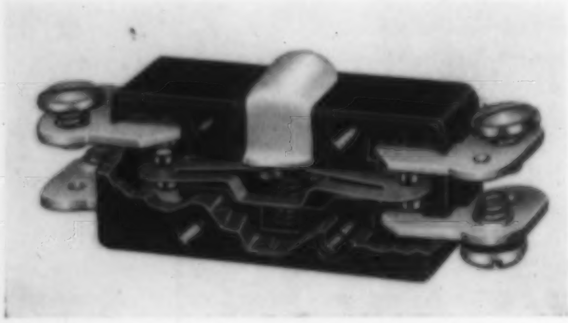


Fig. 5—Small snap-action switch uses an over-center spring arrangement to provide quick opening or closing of contacts regardless of rate at which button is depressed. Contacts at both ends of spring provide double break or make action

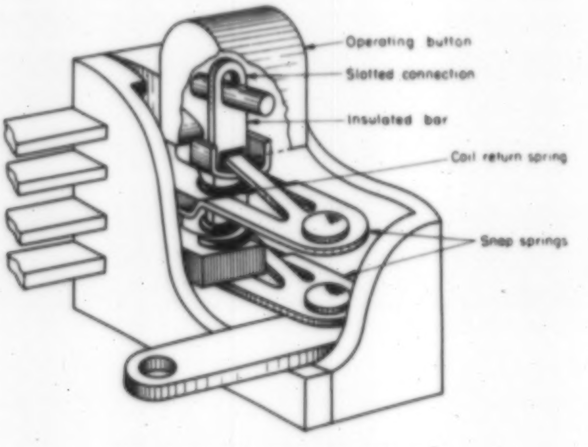


Fig. 8—Two snap switch units in a single case provide double-pole, double-throw operation

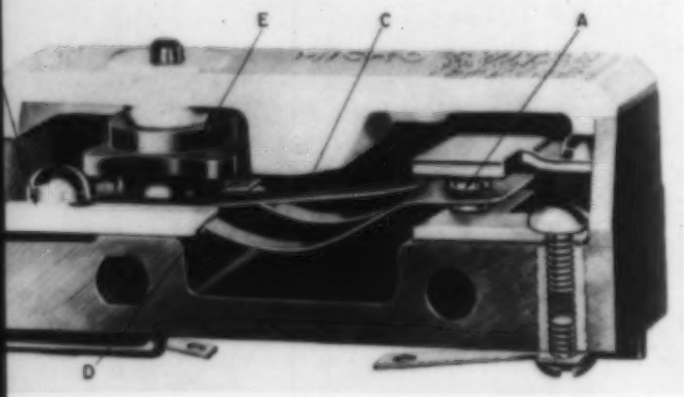


Fig. 6 — In the unoperated position a one piece beryllium-copper spring, *C*, is supported as a cantilever at *M* holding the moving contact *A* firmly against the stationary contact because of the upward force exerted by the side members of the spring. The two side members are in compression and are supported in grooves in anchor *D*. When plunger *E* is pressed against the center member of the spring, the vertical force downward overcomes vertical force upward of the side members, and the moving contact snaps to a lower fixed contact

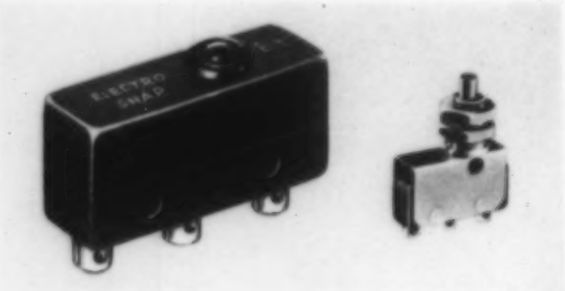


Fig. 7—Accessory operators are fitted to small snap-action push switches to provide more area for thumb or finger and lengthen operating travel. Note the small size of the operating button on the basic switch unit, left

Table 1—Size and Ratings of Typical Miniature Snap-Action Switches

Length (in.)	Width (in.)	Height (in.)	Current Ratings: At 125 or 250 v ac (amp)	At 30 v dc, inductive (amp)	At 30 v dc, resistive (amp)
13/16	1/4	5/16	5	2	2
1 11/16	11/16	13/16	10	. .	. .
1 1/4	1/2	1/2	10	10	. .
13/16	1/4	21/32	5	2.5	4

(Machine Design, October, 1954, Page 154). Electrical ratings are identical with those of the previously discussed types.

Both single and multiple switches are available. Single switches may be of the momentary contact type, which operate only while the button is depressed, or of the locking type.

Multiple pushbutton switch assemblies are available in rows of as many as 20. The rows may be stacked to produce switch banks of almost any desired number, *Fig.* 1. Operation of switches in a row may be one of four types:

1. **Nonlock**—Buttons return to normal position when pressure is released.
2. **Lock-release**—Pushing a button or buttons automatically releases any previously pushed button or buttons.
3. **No two interlock**—Only one button can be pushed in at one time and that releases the previously pushed button.
4. **Accumulative lock**—Buttons pushed stay locked in position until a reset or release button is pushed.

Additionally, when rows of buttons are stacked in banks, the rows may be interlocked in such a fashion that pushing a button in one of the rows will release any previously depressed buttons in the other rows.

Sliding-Cam Multiple Pushbutton Switches: Available with as many as eight buttons controlling 14 contacts, these switches are ordinarily used for appliance controls at ac voltages of 125 or 250. Current rating for resistance loads is 20 amperes. Horsepower ratings for motor control are 1½ hp at 120 v ac and 2 hp at 240 v ac.

Contact arrangements are usually specified by the user for a particular application, and switches are built to order. This fact will usually limit application of these switches to products to be produced in reasonably large quantities. Some typical switch setups, *Fig.* 2, demonstrate the types of contact arrangements available.

In operation, depressing a push button causes the laminated phenolic cam strips to slide in the molded phenolic base. Raised portions on the cam edges then move under or out from under contact leaves to make or break the proper circuits, *Fig.* 3. At the same time, cam holes in the faces of the sliding cams raise any previously depressed button.

The buttons are available in black, white or a variety of colors to facilitate button identification, *Fig.* 4. Terminals may be solder lugs, binding screws or quick-connect terminals.

Miniature Snap-Action Push Switches: Small size and relatively high ratings characterize these switches. Both rotary and lever-operated adaptations of this switch type have been discussed in previous articles. Basic unit of these adaptations is the push-operated switch to be discussed here.

Snap action is the result of switch construction, *Figs.* 5 and 6. This snap action or fast opening and closing of contact points, regardless of force and the rate at which it is applied by the operator, makes possible high contact ratings in a small package, *Table* 1.

Although basic switches are push-operated units,

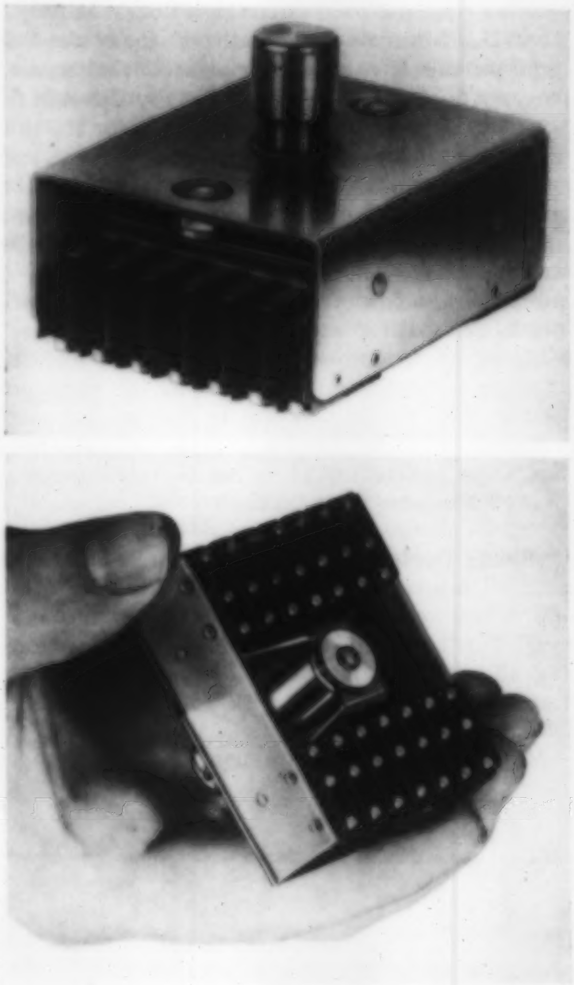
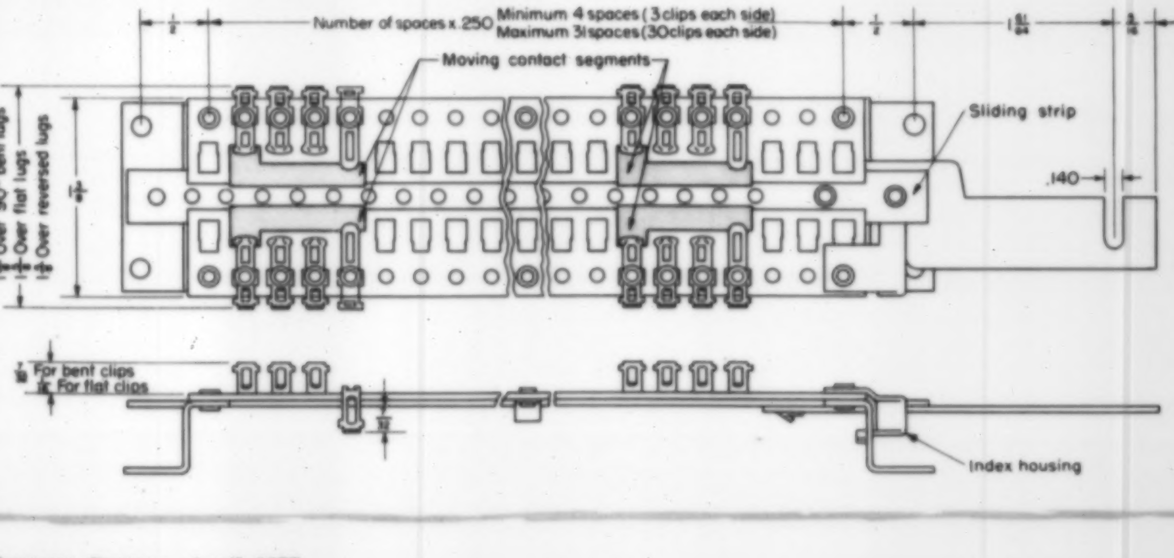


Fig. 9 — Above — Ganged snap-action push switches offer versatile switching arrangements in small packages. This particular assembly consists of 14 single-pole, double-throw subminiature switches operated by a single pushbotton

Fig. 10—Below—Single-slide switch illustrates general construction of switches of this type, which may have a maximum of four positions with 12 poles or two positions with 20 poles



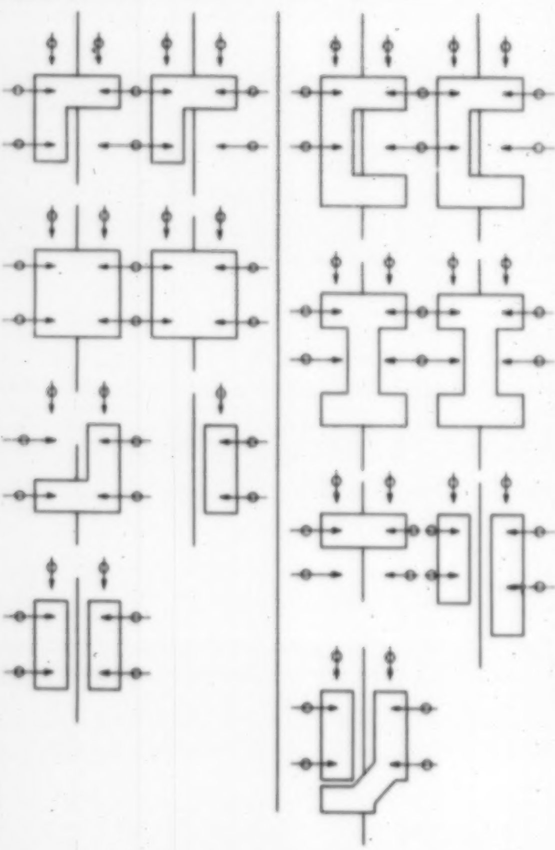


Fig. 11—Sliding contact segments available on a typical multiple-plunger, two position slide switch. Arrows indicate possible locations of fixed contact points. Heavy lines represent the insulated slide

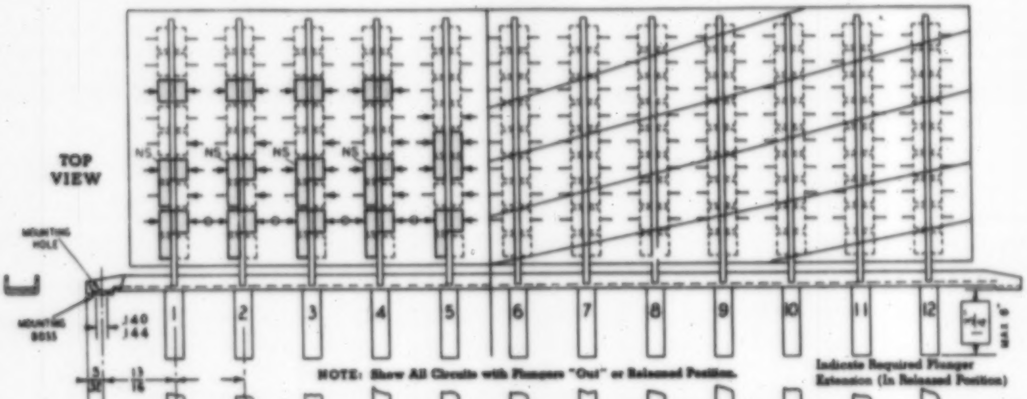
operating button size is usually quite small due to the small size of the switch. Additionally total motion required for switch operation is usually less than 1/16-in. Because both of these conditions tend to make manual operation inconvenient, an accessory push type operator is usually fitted to these switches, *Fig.* 7, to provide more area for the thumb or finger and extend the operating travel.

Contact arrangements of individual switch units are usually single-pole, double-throw with momentary operation. However, double-pole, double-throw switches have been constructed by coupling two units in a single case, *Fig.* 8. Another method providing greater multiplicity of contacts is the ganging of a number of these switches for simultaneous or sequential operation by the same push-button, *Fig.* 9. In addition to momentary-contact versions of these switches, reset switches which maintain contact until a small reset button is pushed are sometimes available.

Sliding Contact Push or Pull Switches: A sliding strip of insulating material is used to carry shorting or contact-making segments in switches of this type, *Fig.* 10. Single-slide switches, those with only one sliding strip, may have as many as four positions with a maximum of 12 poles or as many as 20 poles with two positions.

Multiple assemblies are usually limited to two

Fig. 12—A sample specification sheet for slide switches shows some of the possible arrangements. Arrows indicate stationary contacts. Solid black areas are sliding contact segments which may be nonshorting (break-before-make) or shorting type. The letters *NS* indicate that nonshorting contact is desired


TOP VIEW
NS
NS
NS
NS
MOUNTING HOLE
MOUNTING BOSS
.140
.144
1
2
3
4
5
6
7
8
9
10
11
12
3/32
13/16
NOTE: Show All Circuits with Plungers "Out" or Released Position.
Indicate Required Plunger Extension (In Released Position)
BOTTOM VIEW

positions for the individual plungers. Contact arrangements may be extremely versatile because of segment shapes, *Fig.* 11, and the possibility of connecting between the individual slides, *Fig.* 12. A maximum of 24 pushbuttons in a single multiple switch of this type is available.

Normal operating method for the multiple slide switches is to interlock all slides with a latch bar so that depressing any button or buttons automatically releases all previously depressed buttons. Any number of buttons when pressed simultaneously will, however, lock in the pressed position. This is the same as the system labelled *lock-release* for leaf-spring multiple pushbuttons. Other commonly available systems are:

1. **Cumulative lock**—All buttons remain depressed until a release button is pressed.
2. **Momentary contact**—One or any number of buttons do not latch and are spring returned when pressure is removed.
3. **Individual locking**—One or any number of buttons lock when depressed and do not release until pressed again.
4. **No two interlock**—Only one button can be depressed at one time and pressing a button re-

Fig. 13—Sections through two different makes of heavy-duty pushbuttons show movable contacts which travel with the plunger and the fixed or stationary contacts. Section at left is a contact block without operator while the right-hand switch is complete with operator and oil-tight diaphragm. Right-hand switch has normally-closed as well as normally-open contacts

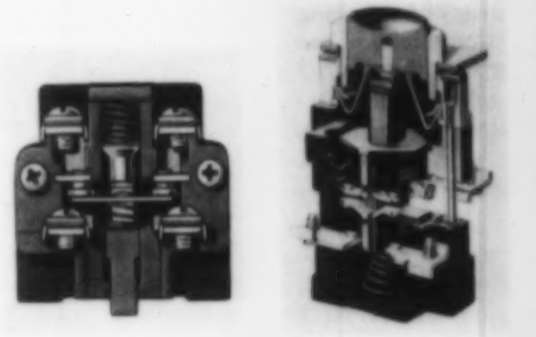
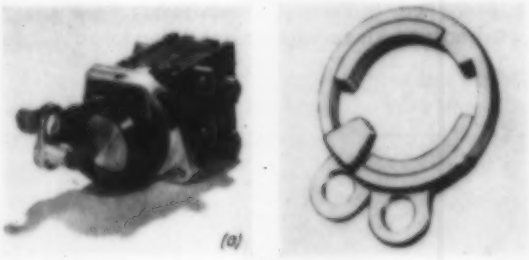
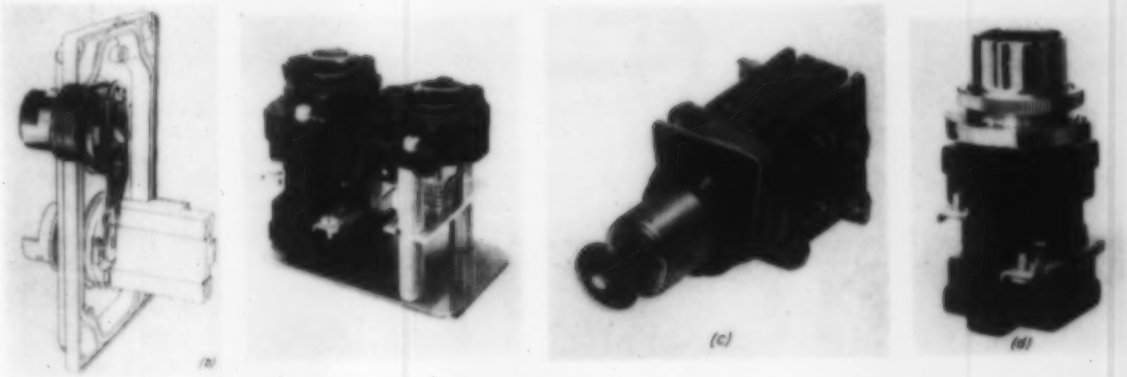


Fig. 14—Pushbuttons are held in the depressed position by attachments, *a*. Padlocks can be used to prevent unauthorized release of the buttons. Mechanical interlocking between the main button and an auxiliary button, *b*, holds contact operating button depressed until release button is pushed. Tumbler-lock and key-operated buttons, c, may be locked in either "off" or "on" position. Rotation of the ring between operator and contact block, *d*, will lock the button in depressed position. A modification of this type can be used to lock a button having both normally-open and normally-closed contacts so that neither set of contacts is closed





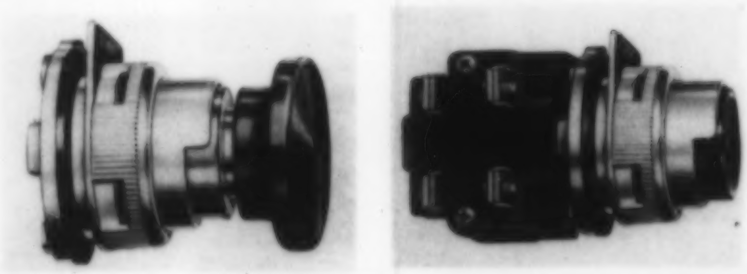


Fig. 15 — An operator, extreme left, when mounted on a contact block makes a complete pushbutton switch unit, left

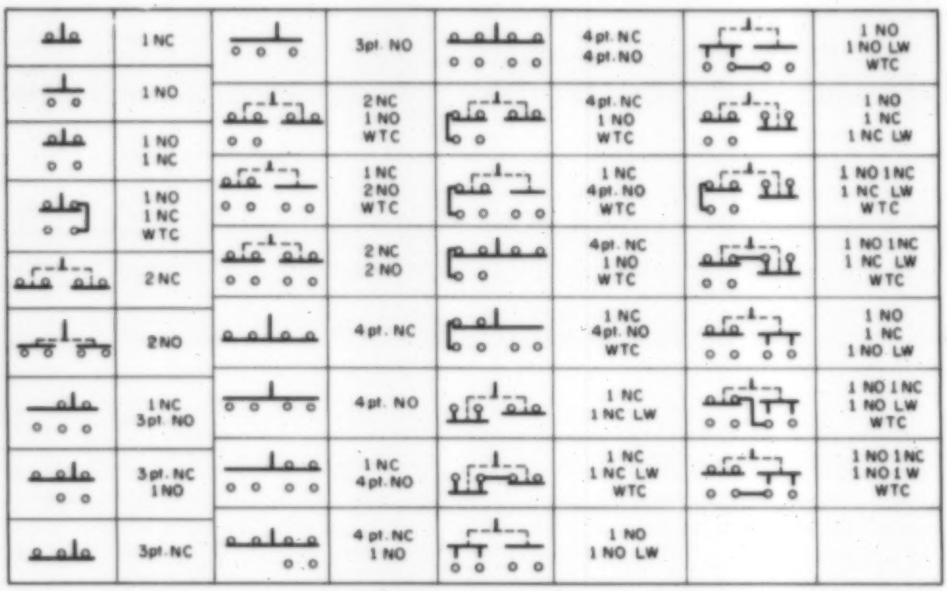
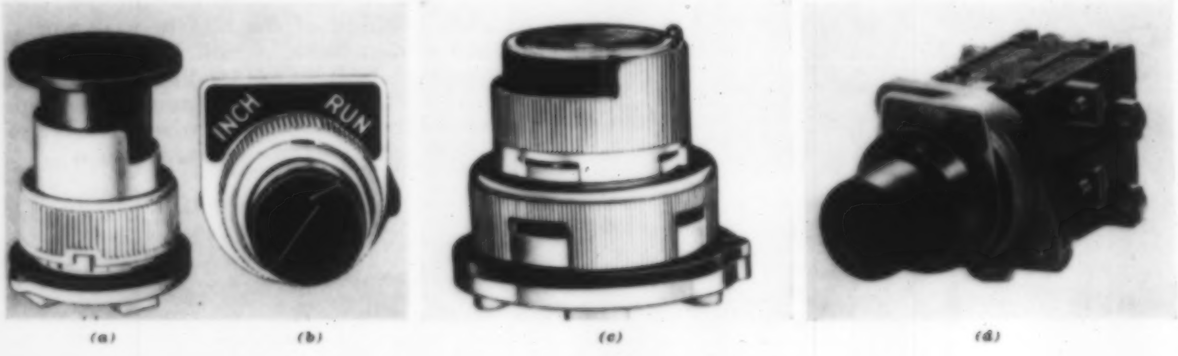

1 NC
1 NO
1 NO 1 NC
1 NO 1 NC WTC
2 NC
2NO
1 NC 3pt. NO
3pt. NC 1 NO
3pt. NC
3pt. NO
2 NC 1 NO WTC
1 NC 2 NO WTC
2 NC 2 NO
4 pt. NC
4 pt. NO
1 NC 4 pt. NO
4 pt. NC 1 NO
4 pt. NC 4 pt. NO
4 pt. NC 1 NO WTC
1 NC 4 pt. NO WTC
4 pt. NC 1 NO WTC
1 NC 4 pt. NO WTC
1 NC 1 NC LW
1 NC 1 NC LW WTC
1 NO 1 NO LW
1 NO 1 NO LW WTC
1 NO 1 NC 1 NC LW
1 NO 1 NC 1 NC LW WTC
1 NO 1 NC 1 NC LW WTC
1 NO 1 NC 1 NO LW
1 NO 1 NC 1 NO LW WTC
1 NO 1 NC 1 NO 1 W WTC

Fig. 16 — A wide variety of switching arrangements can be had in industrial pushbuttons

NO – Normally open. NC – Normally closed. WTC – With tie connection. LW – Longwipe contacts which provide early closing and late opening when normally open and late opening and early closing when normally closed.

Fig. 17—Some of the various types of available industrial pushbutton operators. Mushroom industrial type, *a*, has increased thumb or finger contact area. Selector type, b, selects one of two circuits which may then be operated by pressing the button. Three-position selectors are also available. Half-shrouded pushbutton minimizes the possibility of accidental operation. Extralong pushbutton, d, facilitates operation


INCH
RUN
(a)
(b)
(c)
(d)

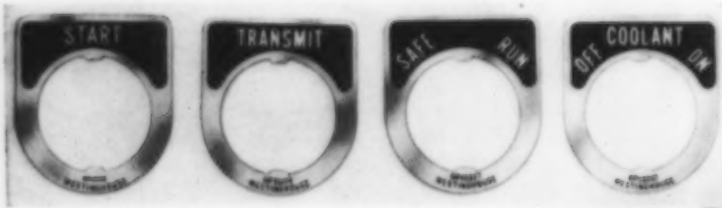

START
TRANSMIT
SAFE
RUN
OFF
COOLANT
ON

Fig. 18—Above—A few of the various legend plates available for use with industrial pushbuttons. Legends may also be molded into the operator button

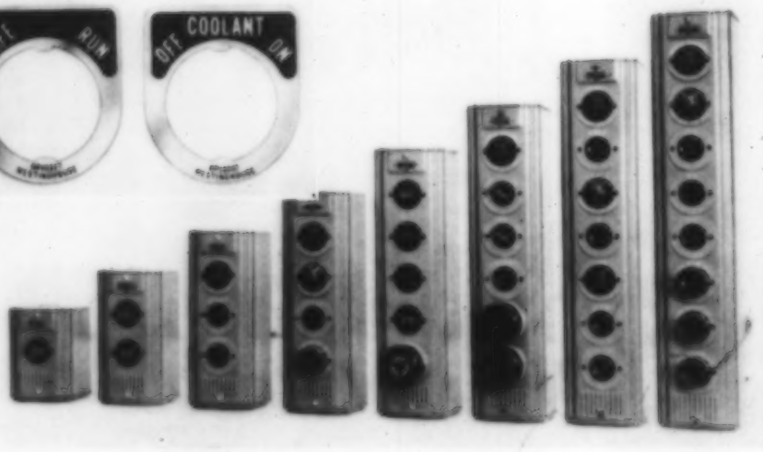


Fig. 19—Right—Pushbuttons may be had in enclosures for machine, conduit or pendant mounting

leases the previously depressed button.

5. **Dual locking**—Two latch bars are used to give independent operation of two groups of buttons.

In addition to these semistandard operating methods, other arrangements may be worked out for specific applications if quantity permits.

Contacts and terminals are made of silver-plated phosphor bronze for normal service or of coin silver for longer life. Terminals are the solder-lug type. Contact ratings are not ordinarily published by manufacturers of switches of this type. One reason is that contact opening and closing times depend on speed at which the switch is operated, since these are not snap-action switches. However, slide switches are ordinarily recommended for low current service such as in high-frequency radio and electronic circuits where currents of less than 100 milliamperes are ordinarily encountered.

Industrial Pushbutton Switches: There are three subclassifications of this general type:

1. Standard duty pushbuttons.
2. Heavy-duty pushbuttons.
3. Heavy-duty, oil-tight pushbuttons.

Difference between standard and heavy-duty classification is in current ratings, *Table* 2. Oil-tight units, as the name implies, are designed to prevent the entrance of oil, coolant, cutting compounds or water. Current ratings of the oil-tight units are equal and in some cases superior to those of the heavy-duty units, being at the upper end of the range of values in *Table* 2.

All pushbuttons of this type, regardless of maker, bear a family resemblance to each other, *Fig.* 13. Contacts are the double-break type in which circuits are both made and broken by two sets of contact points. Basic construction is such as to make them momentary-contact switches. However, various means have been devised to provide locking in the pushed or depressed position, *Fig.* 14.

These switches may be assembled as integral units or by assembly of contact blocks and operators, an operator being the button proper which is pushed by the person using the switch, *Fig.* 15. Use of multiple contact blocks with a single operator produces a variety of switching arrangements, *Fig.* 16. Operator variations also contribute to the versatility of these switches, *Fig.* 17.

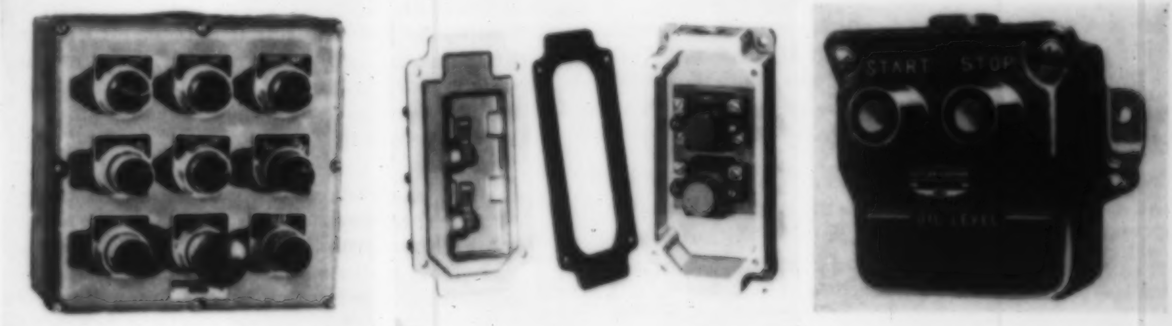
In addition to the wide variety of individual push button units available, manufacturers offer certain other items and accessories to be used in conjunction. Among these are pilot lights and legend plates with a variety of legends, *Fig.* 18. Groups of pushbuttons assembled on panels in enclosures for machine, conduit or pendant mounting, *Fig.* 19, can also be obtained. Enclosures may be for various types of service such as oil-tight and explosion-proof, *Fig.* 20.

These switches are designed for either single-hole or multiple-hole mounting. The multiple-hole types may be mounted either on a front panel or a base plate. Some makes of contact block-operator

Table 2—Inductive Current Ratings of Typical Standard, Heavy-Duty and Oil-Tight Industrial Pushbuttons

AC Voltage (v)	Make (amp)	Break (amp)	Carry (amp)	DC Voltage (v)	Make or Break (amp)	Carry (amp)
Standard Duty						
110	25–30	2–3	10	115	1–1.1	10
220	12–15	1–1.5	10	230	0.5–0.55	10
440	6–7.5	0.5–0.75	10	550	0.1–0.2	10
550	5–6	0.4–0.6	10			
Heavy Duty and Oil-Tight						
110	40–60	6–60	10	115	2.2	10
220	20–30	3–30	10	230	1.1	10
440	13–15	1.5–15	10	550	0.4	10
550	10–12	1.2–12	10			

Fig. 20—Special die-cast enclosures, left, prevent the entry of oil, coolant, cutting compounds or water. A water and dust-tight enclosure, center, is shown with cover removed. Pushbutton units are completely sealed in the enclosure and actuated by auxiliary operators which are a part of the cover. The cast-iron enclosure, right, is designed for use in atmospheres containing explosive vapors or dusts. Contact mechanism may be oil immersed or dry depending upon the type of service



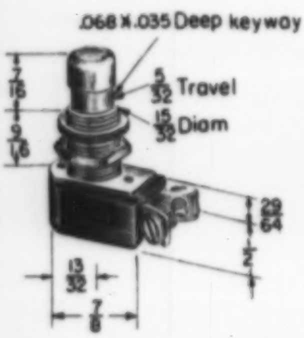
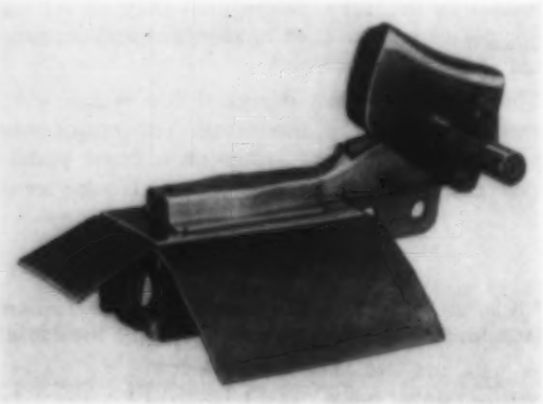


Fig. 21—A typical small appliance switch for single-hole mounting

Fig. 22—Trigger switches such as this are found on a variety of portable electric tools



switches are designed to permit single-hole panel mounting of the operator with the contact block either assembled to the operator or base mounted.

Miscellaneous Pushbuttons: These types are for the most part small plunger-operated pushbuttons, *Fig.* 21, labelled appliance switches by their manufacturers. Available in momentary-contact, double-acting and push-pull types, appliance pushbuttons have single-pole single-throw, single-pole double-throw, double-pole single-throw, or double-pole double-throw contacts. Maximum ratings are 10 amp at 250 v ac and 15 amp at 125 v ac.

Mounting is single-hole in most cases, although multiple-hole types are also available. Terminals may be solder lugs, binding screws or wire leads. Operating buttons may be metal or plastic.

The so-called trigger switches used on portable electric tools are also included in this group, *Fig.* 22. Ratings of these switches are from 6 to 20 amperes at 250 v and from 12 to 15 amp at 125 v. Horsepower ratings are from 1 to 1½ at 250 v.

ACKNOWLEDGMENT

MACHINE DESIGN acknowledges with appreciation the co-operation of these companies in the preparation of this article:

Ark-Les Switch Corp. (*Figs.* 2, 3, 4) Watertown, Mass.
Arrow-Hart & Hegeman Electric Co. (*Fig.* 22) Hartford 6, Conn.
Carling Electric Inc. (*Fig.* 21) West Hartford, Conn.
Cutler-Hammer Inc. (*Figs.* 13, 14, 16, 19, 20) Milwaukee 1, Wis.
Electro-Snap Switch & Mfg. Co. (*Figs.* 5, 7, 8 and *Table* 1) Chicago 24, Ill.
General Control Co. (*Fig.* 1) Boston 34, Mass.
General Electric Co. (*Fig.* 14) Schenectady, N. Y.
Micro Switch Div., Minneapolis-Honeywell Regulator Co. (*Figs.* 6, 9 and *Table* 1) Freeprot, Ill.
Oak Mfg. Co. (*Figs.* 10, 11) Chicago, Ill.
P. R. Mallory & Co. Inc. (*Fig* 12) Indianapolis 6, Ind.
Square D Co. (*Figs.* 13, 15, 17, 20) Milwaukee 12, Wis.
Westinghouse Electric Corp. (*Figs.* 14, 18, 20) Pittsburgh 30, Pa.

Ideas industrial design

upside-down ideas

IT's a cinch to conjure up a few extra ideas on a new design without drawing a single extra line.

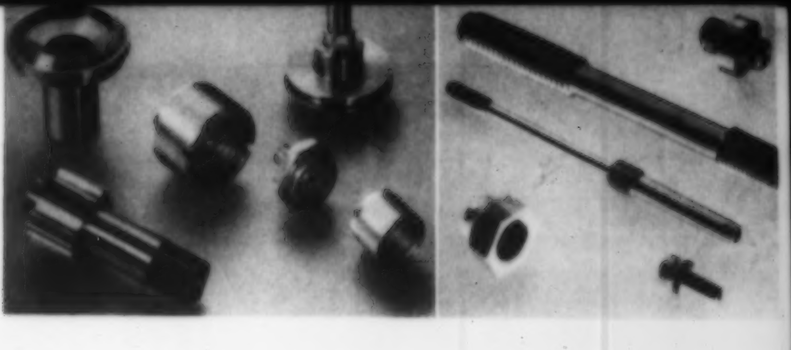
Lets' hope your original layout has some original ideas. Now for a completely fresh approach, just turn the drawing upside down. Does it light any bulbs over your head? Now, turn the drawing over, and then turn it upside down again.

You have now explored four different design possibilities, yet you've made only one drawing.

I'll never forget doing this stunt with a large inspection machine. Everything was to my liking until I turned the drawing over. Then, it became as obvious as the nose on my face that a majority of the controls had been placed at the operator's left hand. The reversed drawing automatically shifted the controls to the right. Came the dawn! Needless to say, no one felt it necessary to make a market study to determine if there might be more right-handed operators than left-handed. As a result, the final design was reversed, and the product was tremendously improved.

Many subsequent experiences have confirmed the worth of this idea. Give it a try some time—even if it doesn't work out in your case, at least you've explored four possibilities and it hasn't cost one extra dime.

—*Cliff*



Design Check List for Screw-Machine Products

FACTORS producing maximum economy in design of screw-machine products are detailed in a recent report of the National Screw Machine Products Association. Information was obtained by questioning the 280 members of the Association. Here, as a check list, are the major factors contributing to good production design:

1. **Use standard sizes and shapes of tubes or bars.** Design the product so that where possible, standard sizes and shapes, commonly used in the screw machine process, may be specified. Rounds, squares and hexagons are typical. But other preshaped forms of bar stock, even suitable as semiformed gear teeth for example, are available.

2. **Avoid unnecessary fancy horizontal shapes.** These run up production costs and are not justified unless absolutely necessary.

3. **Avoid square-bottom holes.** They are expensive in any manufacturing process.

4. **Allow sufficient depth of blind holes.** Clearance of metal chips produced in grinding or thread cutting must be permitted.

5. **Avoid sharp outside corners.** They can increase costs of manufacturing, also are more subject to shipping damage and expense. A bevel edge or countersink is preferable. If it is permissible to remove corners, the limits should be specified.

6. **Steer away from overly sharp inside corners.** They should be eliminated unless their importance outweighs added production cost. Frequently a chamfered corner not only saves costs but also increases part strength. Also, in some cases, undercutting at the angle point may permit the same function as a square corner, at a lower cost. Usually an undercut has no important effect upon either the strength of the part or the effectiveness of the bearing surfaces.

7. **Avoid nonstandard threads and special-diameter holes.** These require special tools and special gages, both items of extra production cost.

8. **Avoid excessively close tolerances where possible.** These entail extra supervision, more expensive tooling, and frequent tool and machine adjustments. Excessively small tolerances simply represent an unnecessary expense.

9. **Don't demand removal of burrs unless essential.** Sometimes it is desirable to have outside burrs removed when inside burrs can remain, and vice versa. For some purposes, however, burrs are of no consequence. Also, the removal of tool marks is not always necessary and usually involves additional cost.

10. **Watch hole location precision.** Don't require that holes be precisely located when they have no definite relation to keyways or other functions. Special jigs and fixtures are necessary when precision is required.

11. **Prefer large chamfers.** When chamfering a corner, a larger chamfer is preferable to eliminate additional necessary machining. In countersinking, especially a threaded surface, a broad angle is less likely to cause imperfections.

12. **Use only approximate numbers on knurls.** If knurls are required, use of only an approximate number permits a less-expensive automatic process. Although it may yield 29 points instead of 30, such a difference is often trivial.

13. **Don't specify threads all the way to a shoulder.**

14. **Dimension in fractions if possible.** When a diameter surface does not fit another part, it is usually best to specify the diameter in fractions of an inch. The part can be made from standard size materials, and the fractional dimension (instead of decimal), will indicate that a close tolerance is unnecessary.

15. **Choose materials with maximum machinability.** Excessively hard materials are normally more expensive, increase machining costs.

16. **Don't require supersmooth finishes.** A hidden part, a part not involving a friction factor, or an exposed part whose appearance is immaterial may as easily be left rough, at a considerable cost saving. As a natural process sequence, most screw-machine products are machined beyond maximum requirements.

17. **Be specific about hardness, elongation and binding tests.** By naming the testing method if required, and the physical properties desired, costly confusion is avoided.

18. **Dimension surfaces to be finished correctly.** If the buyer is to heat treat or plate, dimensions should be given prior to finishing. If the supplier, however, will heat treat or plate, dimensions should be shown after heat treating or plating. Plating thickness should also be given. In addition, special pitch diameters before plating require special gages and are costly. For plating threaded parts, specify unified thread standards to take advantage of standard gages which will allow for addition of plate.

19. **Avoid concentricity where possible.** Where it is essential to proper function, however, it should be shown in terms of total dial indicator reading, and the point of measurement clearly shown on the blueprint.

20. **Avoid unnecessary second operations.** They are normally more expensive than automatic screw-machine operations. Often, the redesigning of a product eliminates a second process by combining it with the original machine operation.

Design Manual

Mechanical Adjustable-Speed Drives

Part 1

By Leo F. Spector

Associate Editor
Machine Design

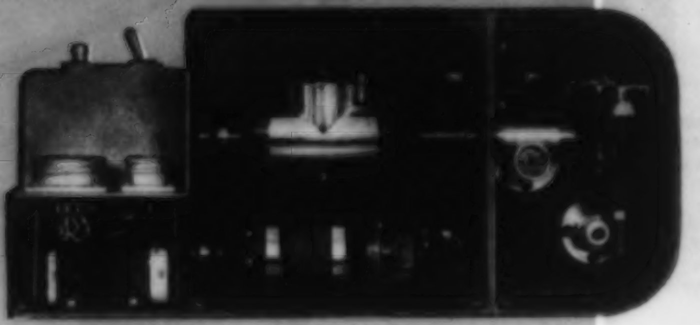


Fig. 1—Drive assembly of small oscillograph for aircraft applications. Miniature 1/40-hp mechanical speed changer controls paper speed under adverse acceleration and temperature conditions, weighs only 6 oz. Photo, courtesy Metron Instrument Co.

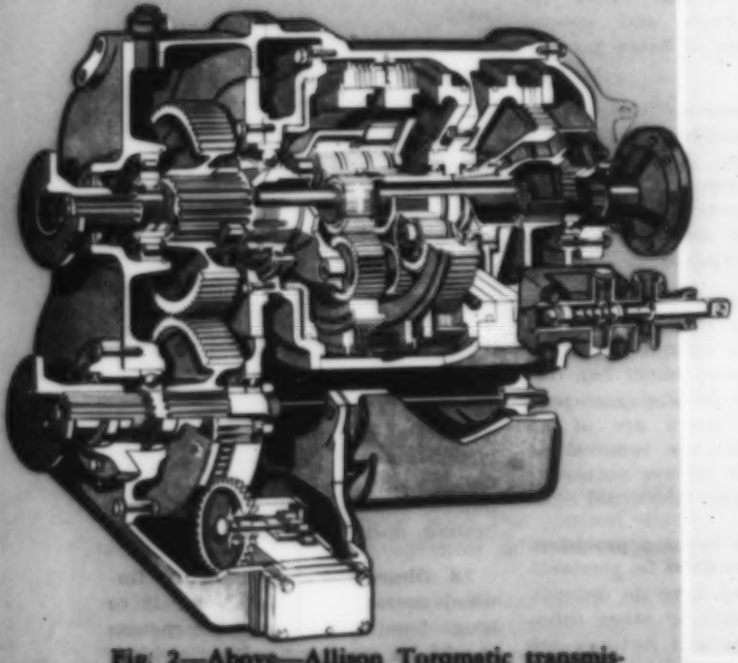


Fig. 2—Above—Allison Torqmatic transmission for heavy-duty truck service. Planetary gearing provides three speeds forward, one reverse, and permits shifting under full load and power without manual clutching. Photo, courtesy Euclid Div. of General Motors Corp.

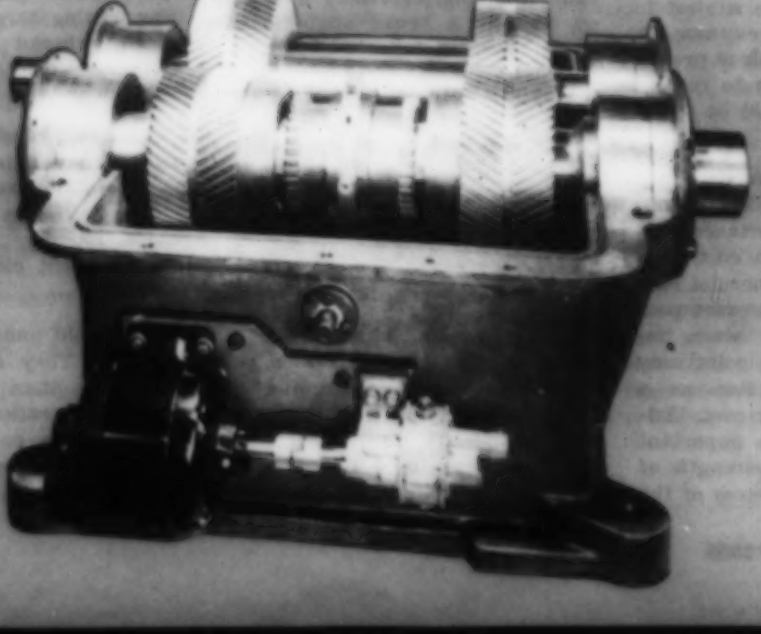


Fig. 3—Right—Two-speed herringbone gear transmission for printing press drive. Slow speed permits control of paper web during initial threading; high speed is for normal press operation. Motor-driven pump on housing maintains constant oil pressure. Photo, courtesy Link-Belt Co.

Fig. 4—Right—Elgin lathe with built-in adjustable-speed V-belt drive which uses a two-speed motor to obtain infinite variation of spindle speeds from 120 to 3900 rpm. Photo, courtesy Worthington Corp.

Most simple, direct, and often least-expensive methods of speed adjustment are those employing mechanical principles.

This two-part series is a basic guide to the selection of all kinds of mechanical adjustable-speed drives:

1. **Stepped**
2. **Stepless, limited range**
3. **Stepless, infinite range**

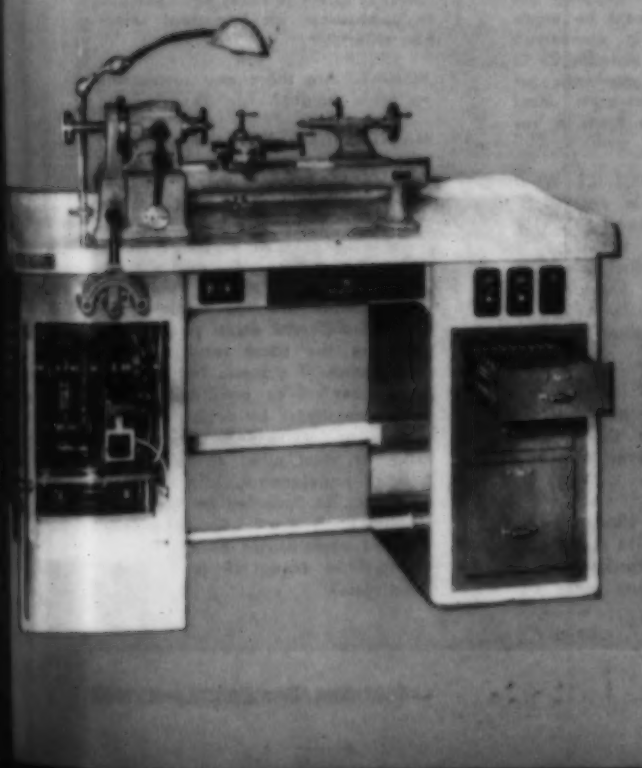
The first two classes are covered in this part. The third class will be discussed in the second part which will also include a summary of selection and application factors. This series is a companion guide to "Adjustable-Speed Electric-Motor Drives," October 1954. Still other methods of speed adjustment, including fluid-power systems, will be covered in future design manuals.

ADJUSTABLE-SPEED is frequently a problem with many possible solutions. Countless drive systems have been developed and often provide several alternatives from which to choose. For the majority of machine applications, however, mechanical speed changers are eminently suited and often provide the simplest and most economical answer.

Potential applications of mechanical systems range from low-power instrument drives, *Fig.* 1, to heavy-duty automatic truck transmissions, *Fig.* 2. They may be used to provide a few exact speeds, *Fig.* 3, or to vary speeds infinitely over a wide range, *Fig.* 4. Efficiency of power transmission generally runs high and for most units is over 90 per cent.

Drive systems vary from the simple variable-pitch sheave on a motor with an adjustable base, *Fig.* 5, to complete packaged drives, *Fig.* 6. Basically, however, a mechanical speed changer is only a component of a complete drive assembly which may take many forms. This feature is often a distinct advantage when the speed of parts of a machine or process must be separately adjusted. Generally, a one or two-speed electric motor is used as the power source, but other prime movers are equally suitable. From the standpoint of costs, the advantages of a system using a constant-speed motor and a mechanical speed changer have long been recognized.

In the majority of applications, speed control is obtained manually by means of a lever, handwheel, or knob. Remote or automatic control is usually equally feasible, *Fig.* 7, but some type of positioning motor arrangement is generally nec-



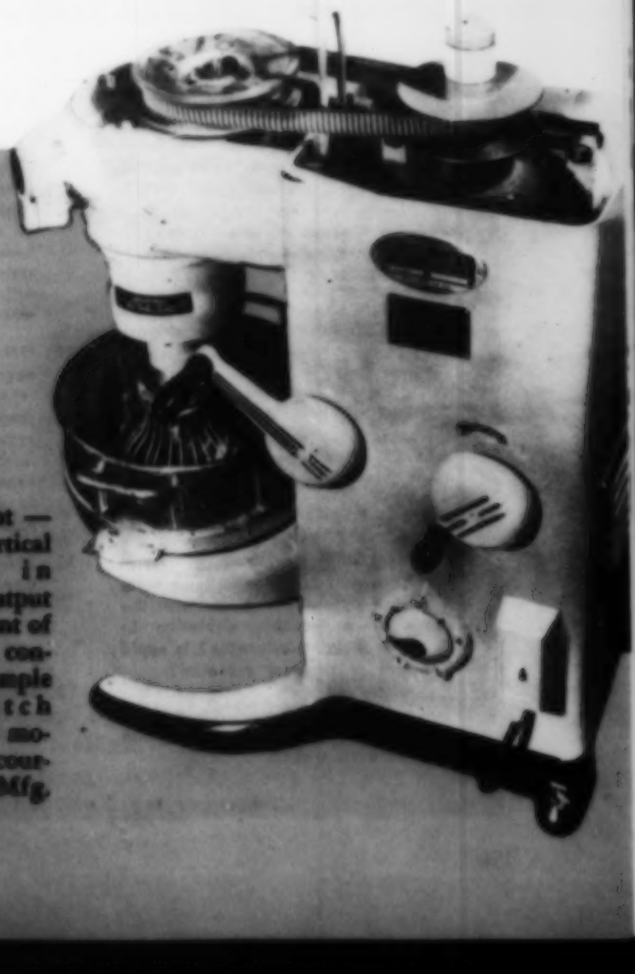
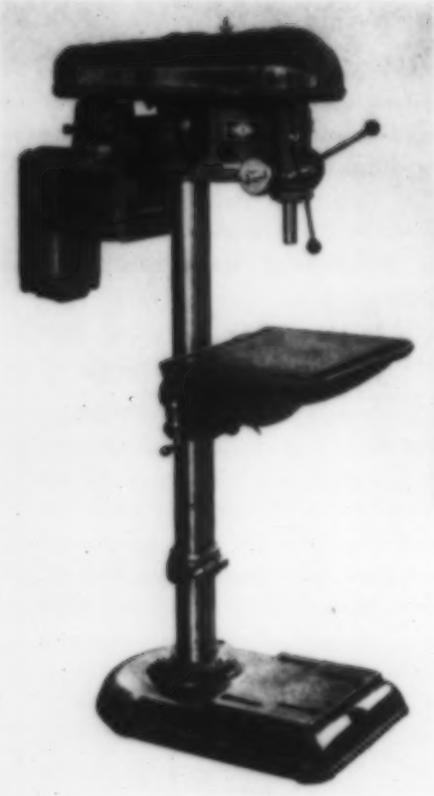


Fig. 5 — Right — Blakeslee vertical dough mixer in which 3:1 output speed adjustment of V-belt drive is controlled by a simple variable - pitch sheave on the motor. Photo, courtesy Gerbing Mfg. Corp.



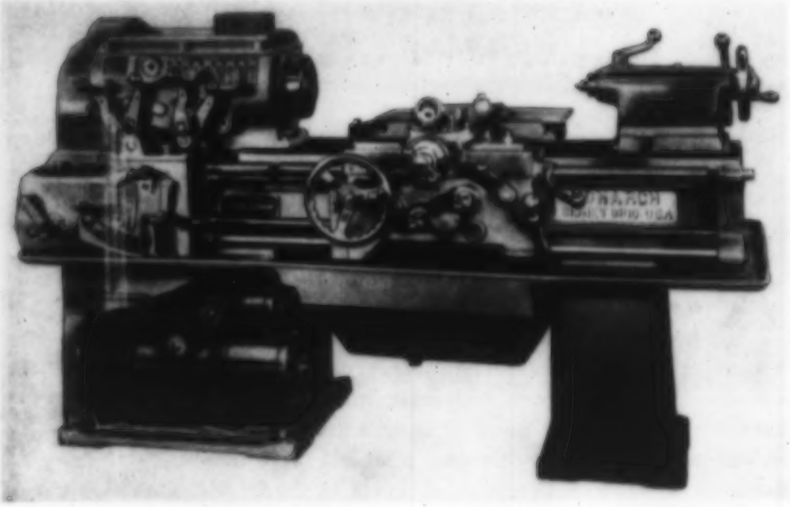


Fig. 6—Left—Delta drill press with built-in adjustable-speed power package containing a V-belt transmission and motor integrally mounted. Photo, courtesy U. S. Electrical Motors Inc.

Fig. 7—Above—Monarch lathe with electric remote-control system for traction type adjustable-speed drive package mounted in base. Control station and speed indicator are on top of lathe for easy accessibility. Photo, courtesy Master Electric Co.

Table 1—Check List of Adjustable-Speed Drive Requirements

1. *HORSEPOWER REQUIREMENTS:* What is the maximum horsepower to be transmitted? How does horsepower requirement change with speed?
2. *SPEED RANGE:* What are the maximum and minimum output speeds? Their ratio? Does the range pass through zero and include negative (reversed) speed values?
3. *NATURE OF SPEED VARIATION:* Should speed variation be infinite (stepless) over the range or in a definite number of steps (stepped)? Is a uniform or nonuniform rate of variation required?
4. *SPEED REGULATION:* What are the limits of permissible speed deviation that can be tolerated at any speed setting?
5. *TORQUE REQUIREMENTS:* What is the maximum torque to be transmitted? How does torque requirement change with speed?
6. *LOAD CHARACTERISTICS:* What changes of load have to be expected at different speeds? If load varies, how is the load-speed relationship affected? What are the limits of permissible deviation in the load-speed relationship? Is rapid stopping or reversal essential?
7. *DIRECTION OF ROTATION:* Is drive operation to be in one direction only or both ways?
8. *TYPE OF SERVICE:* Are loads steady, pulsating or subject to heavy shock? Are speed changes to be frequent or infrequent? What frequency of starts and stops as well as load reversals are anticipated? Is operation to be normal (8-10 hours per day), continuous (24 hours), or intermittent?
9. *SPEED ADJUSTMENT:* Can speed adjustment be made by stopping the drive or must adjustment be made while the drive is in operation? Is manual operation suitable or is some form of semiautomatic or automatic control necessary? Must adjustments be made from a remote location?
10. *OPERATING CHARACTERISTICS:* What degree of reliability is necessary? Is high efficiency of power transfer essential? Is quiet operation a requirement? Will dissipation of heat be difficult or undesirable? What life expectancy is required? Is simplicity of operation and adjustment important?
11. *SPACE REQUIREMENTS:* Are there any restrictions on size of the drive units? It is desirable that speed changer and prime mover be separate? Or integral?
12. *SPEED OF RESPONSE:* How rapidly must the drive respond to speed adjustments? Is time of response critical? How rapidly must loads be accelerated and decelerated?
13. *ENVIRONMENTAL CONDITIONS:* What are the temperature and humidity conditions of the operating environment? Is air circulation provided? Will the drive be exposed to vapors, dust, fumes, flying liquids or solids, corrosive atmospheres or extreme weather conditions? Is shock or vibration prevalent? Must unusual safety features be provided? Is appearance an important selection criterion?
14. *WEIGHT:* Are there any restrictions on drive weight?
15. *MAINTENANCE:* Will the drive be accessible for inspection, lubrication and periodic maintenance? Is periodic maintenance or servicing to be expected? Or must the drive be capable of operating for long periods without attention?
16. *COST:* What are the comparative costs of different drive systems for obtaining the same result? Is a combination of systems feasible? Is special control or auxiliary equipment necessitated by design requirements? Is first cost the determining factor or must other considerations such as maintenance, idle machine time, etc., be included in the overall cost evaluation? Can any features of performance or control be sacrificed in favor of further reduced costs?

essary for such applications. Other systems employing hydraulic, mechanical or pneumatic devices are also widely used.

Speed adjustment can be accomplished mechanically in several ways. In this, and the article to follow, all of the common mechanical adjustable-speed systems in general use today, their application possibilities and limitations, will be discussed.

The following discussion treats certain basic considerations of selection and application. A more detailed analysis of overall selection and application factors will be presented in the second part of this series.

Basic Considerations: Selection of the best method of speed adjustment for a particular application requires careful analysis of a number of interrelated factors. The check list in *Table* 1 may be of assistance in evaluating application requirements.

A comparison of the characteristics of the different available methods of speed adjustment with the requirements established from this check list will often narrow the range of selection possibilities to one or two best types. Where adjustable-speed drive requirements fall within the low or moderate horsepower ranges, and special operating conditions do not dictate the use of electrical or hydraulic devices, it will be found that mechanical units offer a number of desirable features, not the least of which is low cost.

Controlling factors in the selection of a mechanical unit are usually the power, speed, and torque characteristics of the load. Horsepower limitations are particularly restrictive and act to narrow selection alternatives severely in the high power ranges. For example; above 90 hp adequate capacity could only be obtained through some form of gear system or a multiple V-belt drive with limited range. In the case of commercial units providing forward, zero and reverse speeds, capacities are limited to a maximum of 20 hp, and for several of the types do not exceed 5 hp. However, in the fractional to 15-hp range, which is generally the area of greatest design concern, a wide array of mechanical devices is available to meet almost any combination of application requirements.

Table 2—Typical Service Factors for Adjustable-Speed Drives

Duty	Daily Service (hr)	
	8	24
Light Uniform or steady load never exceeding horsepower rating, infrequent starting	1.0	1.5
Moderate Heavy inertia, moderate shock, frequent starting conditions; peak loads do not exceed 125 per cent average horsepower	1.25	1.75
Heavy Heavy shock conditions or frequent reversing. Peak loads do not exceed 150 per cent average horsepower	1.5	2.5

Load requirements in adjustable-speed applications can be separated into three general types: (1) Constant torque (horsepower varies directly with speed); (2) constant horsepower (torque varies inversely with speed); and (3) variable horsepower, variable torque (where torque and/or horsepower vary as a power of the speed). A survey of torque-horsepower requirements over the full speed range will be necessary to establish the load pattern for a particular drive application.

Constant torque is the most common requirement, and is exemplified by applications such as conveyors, printing presses, compressors, etc. Constant horsepower requirements are found in a number of machine tool applications, such as lathes, milling machines, punch presses, etc., where the full capacity of the drive must be utilized at all speeds. The third group, variable torque and variable power, includes centrifugal pumps and similar equipment such as fans and blowers where, for example, horsepower is a function of the square of the speed.

With few exceptions most types of available mechanical speed changers are essentially torque converters and, when coupled to a constant speed-constant power input, transmit a decreasing torque as speed increases. This general characteristic has a significant influence on the selection of a particular unit and must be taken into account. For example, in constant-torque applications, selection would be based on maximum power requirements at maximum speed to assure adequate torque capacity at any speed. If horsepower is to be constant throughout the speed range, the critical condition of selection occurs at minimum speed where torque is at a maximum and imposes the severest strain on mechanical parts. A power requirement that decreases slightly with increase in speed would, of course, be evaluated on this same basis. For variable torque, variable horsepower applications, maximum power at maximum speed is the controlling condition. In this case, because of the power-speed relationship, capacity at the lower speeds will necessarily be far in excess of requirements.

In determining the horsepower rating of a mechanical unit, allowance should be included for the type of service and duty cycle. This corrected or catalog rating can be found by multiplying the actual transmitted horsepower by a service factor corresponding to the operating conditions. Although manufacturers of commercial units are usually conservative in their ratings, the use of a service factor in horsepower calculation is generally recommended and will act to reduce maintenance and increase equipment life and reliability. Typical service factors are given in *Table* 2. These values have not been standardized across industry,

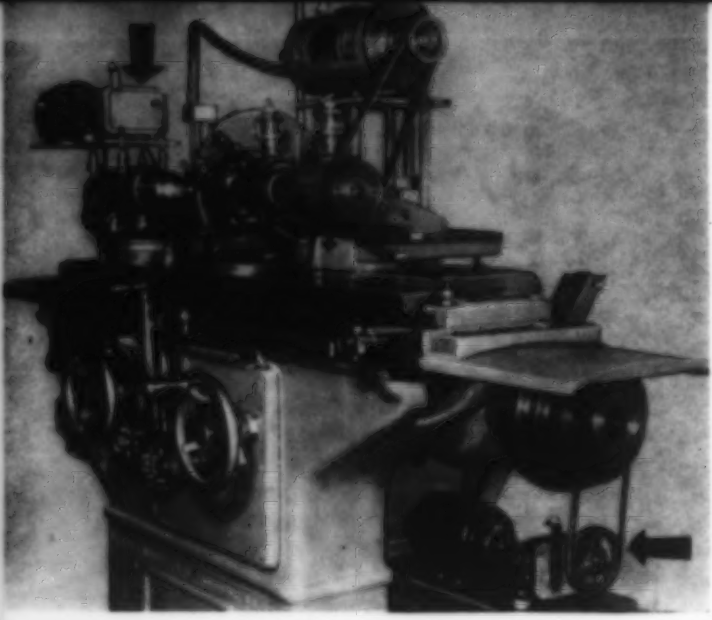


Fig. 8—Cylindrical grinder with two adjustable-speed transmissions of infinite-range type. Table travel of zero to 57 inches per minute is provided by 1/12-hp drive at lower right. At upper left 1/15-hp drive permits workhead speed to be varied from zero to 500 rpm or gives positive dead-center drive, through shaft extension, when workhead is disengaged. Photo, courtesy Revco Inc.

but the ones given in the table are representative of average practice.

In discussing methods of speed adjustment, certain terms are helpful and perhaps should be defined. Basically, two kinds of speed variation—"stepped" and "stepless"—are possible. Multiple-gear transmissions and stepped pulleys which provide a specific number of output speeds at fixed ratios are examples of the stepped type, *Fig*. 2. Stepless types, on the other hand, permit speed to be varied in infinitely small increments over the entire speed range. Typical examples are the variable-pitch V-belt sheaves and all-metal traction devices which permit smooth gradual speed variation over a specified range, *Fig*. 4. According to application requirements, a drive may require either or both types of speed variation.

Units of the stepless type can further be classified according to speed range. If the ratio of maximum to minimum output speeds is a positive number (constant direction of rotation), the adjustable-speed device is defined as one of "limited" range. However, if the speed range includes zero speed, and perhaps extends to a negative value of minimum output speed (reversed direction of rotation), the unit is one of "infinite" range. For example, an adjustable-speed V-belt drive which uses variable-pitch sheaves to obtain stepless speed variation over the range of 125 to 250 rpm has a speed ratio of 2:1 and thus falls in the limited range category. However, a transmission of the mechanical differential or variable-stroke type which provides smooth speed adjustment over the range from zero to 500 rpm has an infinite speed range, *Fig*. 8.

From the foregoing discussion, all mechanical methods of speed adjustment can now be separated conveniently into three categories based on the nature of speed variation and range:

1. Stepped
2. Stepless, limited range
3. Stepless, infinite range

Each of these groups and the corresponding mechanical units, their operating principles, application factors and limitations, will be discussed.

In addition to the foregoing terminology, there is one other distinction—stationary control and motion control—that is commonly used with mechanical equipment. Stationary control refers to units which require the drive to be stopped before speed adjustments can be made. Motion control units permit adjustments while the drive is in operation. Both types in each of the different general categories will be covered.

Stepped Speed Adjustment

Mechanical methods of stepped speed adjustment include a number of friction and gear devices. The primary advantage of all these units is that they make available a fixed number of speeds, and permit speeds to be preset or controlled at a constant ratio, often with a high degree of accuracy.

A classic example of the need for stepped speed control in certain types of applications is furnished by the case of a lead screw on a lathe. A stepless adjustable speed unit could undoubtedly provide the desired range of spindle speeds but, at the same time, would be impractical. Exact speed control is required and the application is one for gearing.

When a unit of the stepped type is employed, it must be remembered that all possible speed conditions should be considered. If the best operating speed falls between two of the available speed settings, a loss in performance, and productivity, will result. Where there is a possibility of speed variations at different speed settings, a stepless system may be more practical, *Fig*. 9.

Stepped Pulleys: Perhaps the oldest and most familiar methods of stepped speed adjustment are the traditional stepped pulley systems, *Fig.* 10. Both V-belt and flat belt types are commonly used. Applications have been limited primarily to machine tools and the flat belt designs are largely being replaced by V-belt systems or gear transmissions, *Fig.* 11.

Speed changes are accomplished manually by shifting the belt to different steps with the drive shut down or with one pulley disengaged by means of a clutch. These systems are probably the least expensive of all methods of speed adjustment and are frequently used with back gearing for added range. On the other hand, belt slippage tends to be high, affecting drive efficiency and speed control. Belt maintenance is usually relatively high. Speed and torque ranges are limited by practical pulley sizes and are not as wide as can be obtained with gear transmissions.

In the design and application of stepped pulleys, primary requirements are: (1) Ratio of diameters of corresponding steps must give desired speed ratios and (2) diameters of any mating pair of steps must be such as to maintain proper belt tension in all positions. Pulley dimensions may be established from the following relationships. For open belt systems, such as shown in *Fig.* 10,

$$\frac{\pi}{2}(D_1 + d_1) + \frac{(D_1 - d_1)^2}{4C} =$$

$$\frac{\pi}{2}(D_2 + d_2) + \frac{(D_2 - d_2)^2}{4C} \qquad (1)$$

and

$$\frac{N_2}{N_0} = \frac{D_2}{d_2} \qquad (2)$$

where N_0 = speed of driving shaft and N_2 = speed of corresponding driven pulley. Other nomenclature is given in *Fig.* 10. For crossed belt arrangements, the controlling relationships are given by Equation 2 and

$$D_1 + d_1 = D_2 + d_2 \qquad (3)$$

Symmetrical pulley designs are generally rec-

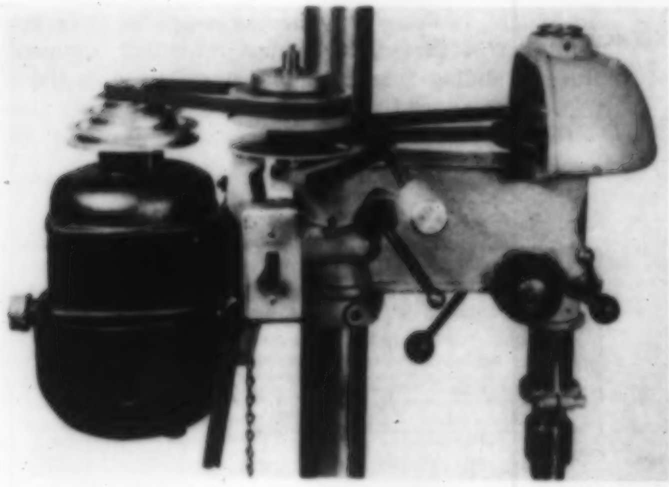


Fig. 9—Above—Drill-press drive converted to stepless speed control with compound-sheave system replacing original stepped design. Photo, courtesy Speed Selector Inc.

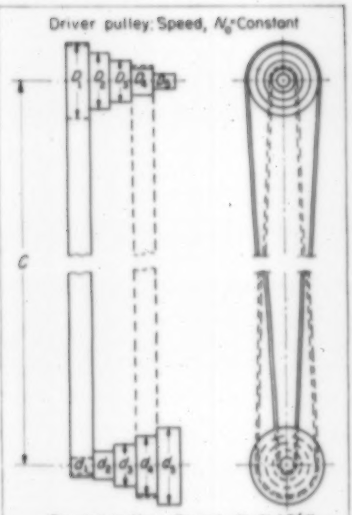
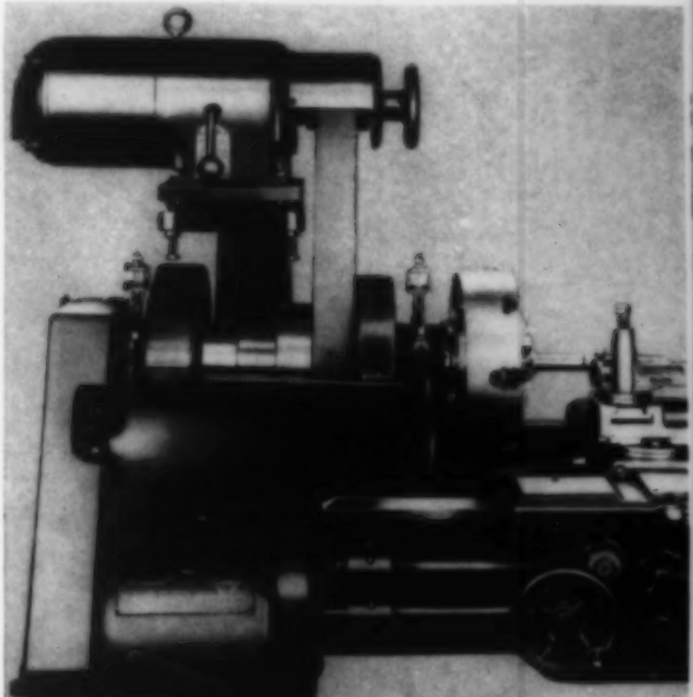

Driver pulley: Speed, N_0=Constant
D_1
D_2
D_3
D_4
D_5
C
d_1
d_2
d_3
d_4
d_5
Driven pulley: Speed, $N=N_0(D/d)$

Fig. 10—Left—Typical stepped-pulley system for use with flat belts

Fig. 11—Converted lathe design with packaged four-speed gear drive replacing conventional long flat belts and overhead line shafts. Rated capacity of 3 hp is developed at all speeds to match machining requirements. Photo, courtesy Lima Electric Motor Co.



ommended from the standpoint of economy and convenience. One method of establishing a symmetrical relationship is to select speeds of the driven shaft so that the speed of the driving shaft is a mean proportional value between speeds at belt positions symmetrical about the middle. For example, in a five-step design the proper speed relationships would be: $N_1/N_0 = N_0/N_5$, $N_2/N_0 = N_0/N_4$ and $N_0 = N_3$. Recommended practice is that the ratio of speeds be approximately 1.2.

In these and other types of belt drives which will be discussed, standard V-belt and flat-belt practice will apply. No attempt will be made here to cover these fundamentals which are treated in detail in the literature.

Contact Pulleys: The phonograph turntable drives shown in *Fig.* 12 illustrate two methods of speed adjustment that have been used to advantage for multispeed, low-power drive applications. Both designs provide turntable speeds of 78, 45 and 33 1/3 rpm and are powered by constant-speed motors of about 1/70-hp capacity. In each case, the turntable is driven through an idler wheel in frictional contact with the turntable rim.

In both of these designs, the combination of a constant-speed motor with mechanical speed adjustment has, from a cost standpoint, proved superior to designs employing centrifugal speed governors to control motor speed.

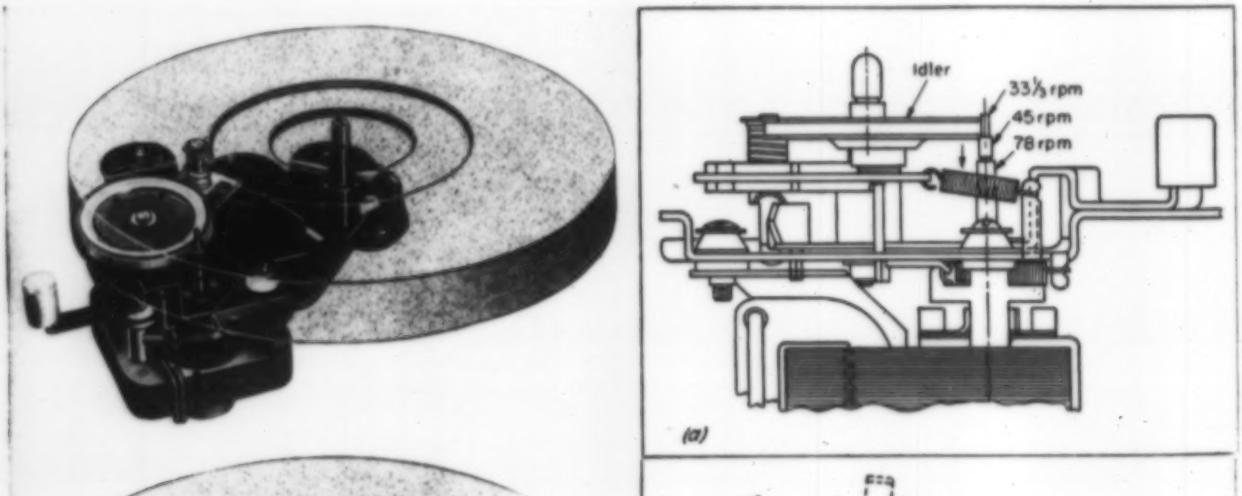
Gear Transmissions: Exact speed control and high efficiency of power transmission have long been recognized attributes of gear drives. Multispeed gear trains have been widely used to advantage in machine tools, automotive transmissions, and innumerable other applications where selective control of a specific number of fixed speeds is necessary. In the following discussion, attention will be focused on selective-speed gear transmissions, their application possibilities and limitations and the commercial units available. Epicyclic gear trains, which include the familiar planetary gear devices, will be treated separately.

Gear transmissions are usually employed to provide low output shaft speeds and high torques, and will handle severe load requirements. With proper design, they are equally suited for high-speed operation and applications are increasing in this direction. Where stops are frequent, some means of braking may be necessary to overcome the inertia forces. Maximum operating temperature of sliding-gear units is usually given as 180 F.

Selective speed gear trains may be roughly classified in three basic gear arrangements, *Fig.* 13:

1. Coaxial input and output shafts. Speed ad-

Fig. 12—Two low-power phonograph drives employing, *a*, stepped diameters on motor input shaft and, *b*, three turret pulleys of varying diameter for speed adjustment. Photos and drawings, courtesy General Industries Co.



justment is obtained by means of sliding gears on one or more intermediate parallel shafts.

2. Parallel driving and driven shafts. Several gears of different sizes are mounted rigidly to one of the shafts and meshed with mating gears, free to rotate on the other shaft. Speed adjustment is obtained by locking different gears individually on the second shaft by means of clutches to obtain a rigid power connection.
3. Parallel driving and driven shafts with idler. One shaft carries several gears of different sizes rigidly mounted. Speed adjustment is obtained through an adjustable arm which carries an idler gear to make power connection with fixed or sliding gears on the other shaft.

Manual-shifting automotive transmissions are usually a combination of the first two principles as shown by the typical arrangement in ***Fig.*** **14**. Countershaft transmissions of the second type usually require individual clutches and may often increase transmission length beyond practical limits. This condition would also be true even if clutches were alternated between the two shafts. Clustered multiple shafts might be used and would act to shorten the gear box but, at the same time, would increase its diameter considerably.

The third system is often employed where speed

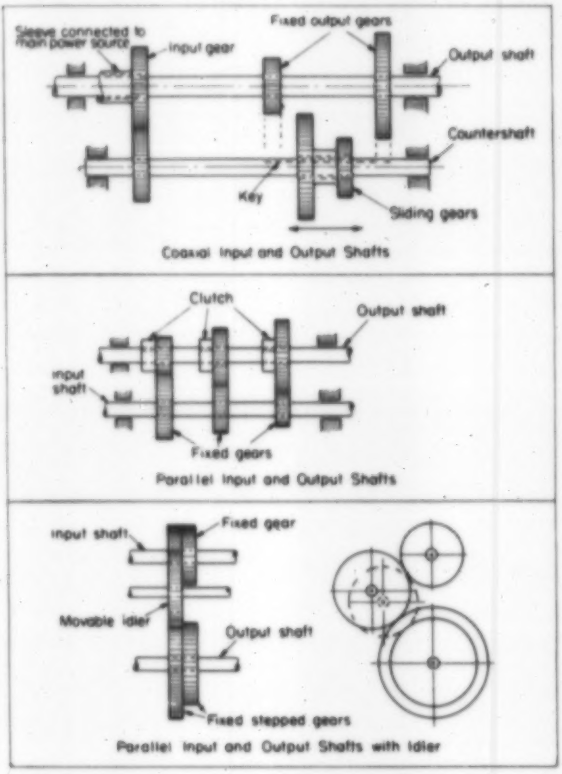

Sleeve connected to main power source
Input gear
Fixed output gears
Output shaft
Countershaft
Key
Sliding gears
Coaxial Input and Output Shafts
Clutch
Output shaft
Input shaft
Fixed gears
Parallel Input and Output Shafts
Input shaft
Fixed gear
Movable idler
Output shaft
Fixed stepped gears
Parallel Input and Output Shafts with Idler

Fig. 13 — Three basic gear arrangements for selective-speed transmissions

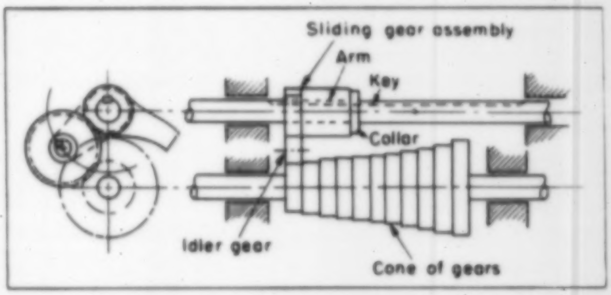
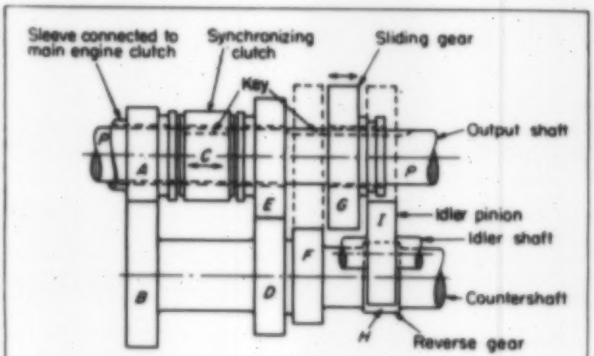

Sliding gear assembly
Arm
Key
Collar
Idler gear
Cone of gears

Fig. 15—Typical cone gear arrangement used in machine tools for adjusting speed in small steps


Sleeve connected to main engine clutch
Synchronizing clutch
Sliding gear
Key
Output shaft
A
C
E
G
I
P
Idler pinion
Idler shaft
F
B
D
Countershaft
H
Reverse gear

Power Flow

First speed : A-B-F-G-P (clutch C disengaged)
Second speed : A-B-D-E-C-P (clutch C engaged to E;G neutral)
Third speed : A-C-P (direct drive, clutch C engaged with A;G neutral
Reverse : A-B-H-I-G-P (clutch C disengaged)

Fig. 14—Gear arrangement for typical four-speed automotive transmission of manual shifting type

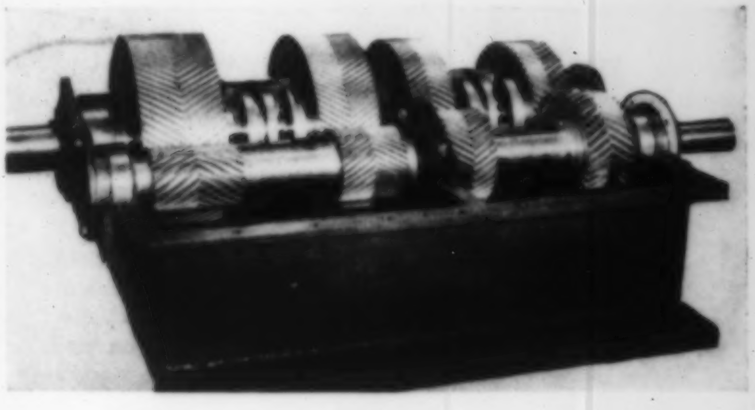


Fig. 16—Four-speed herringbone gear transmission with lever-operated square-jaw clutches for changing speeds. At an input speed of 1750 rpm, unit provides output speeds of 1196, 898, 602 and 452 rpm and has capacity of 75 hp at low speed. Photo, courtesy Link Belt Co.

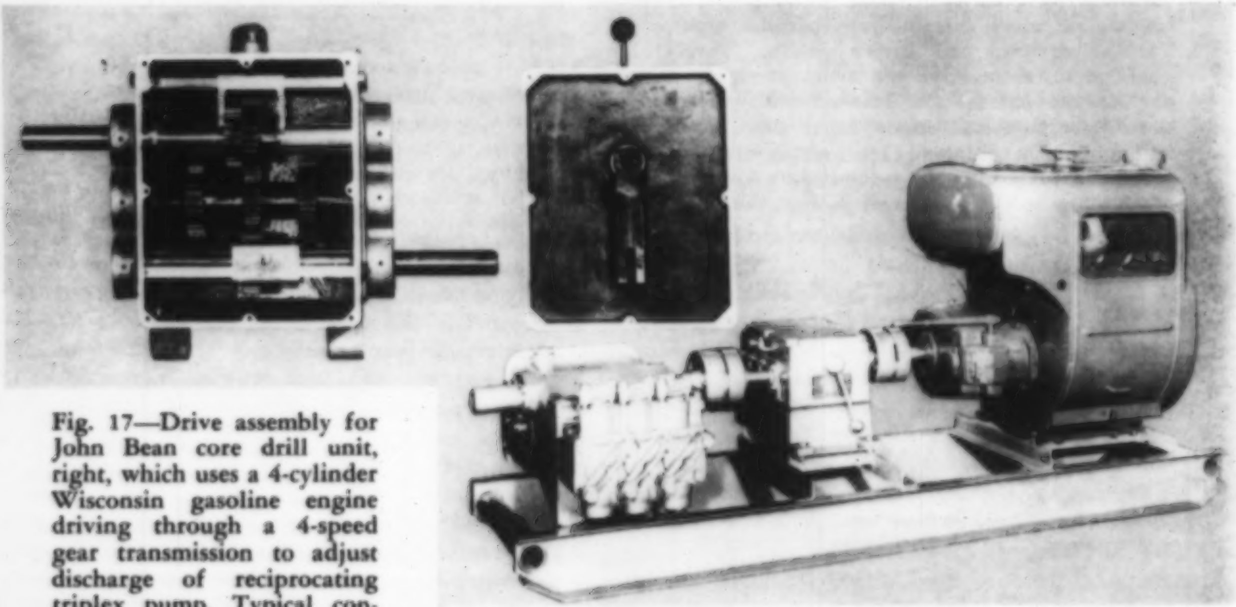


Fig. 17—Drive assembly for John Bean core drill unit, right, which uses a 4-cylinder Wisconsin gasoline engine driving through a 4-speed gear transmission to adjust discharge of reciprocating triplex pump. Typical construction of gear box is shown by similar lever-operated unit, above, with cover removed. Photos, courtesy Turner Uni-Drive Co.

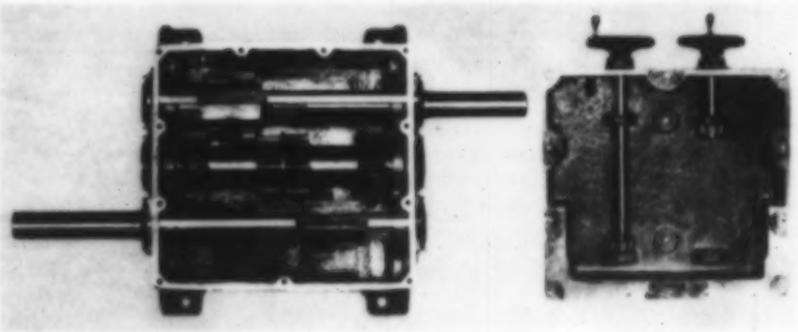


Fig. 18—Right—Four-speed gear transmission with handwheel control of speed adjustment. Photo, courtesy Turner Uni-Drive Co.

steps in small increments are desired, *Fig*. 15. If this train is in turn driven by and/or drives a multispeed train, a wide range of speeds become possible with a constant speed input.

Commercial selective-speed gear transmissions are available in capacities ranging from subfractional to 1500 hp. Most of these units are of the sliding-gear type and, depending on the size and horsepower capacity, provide from two to nine fixed speed selections in a variety of optional ratios, *Fig*. 16. For purposes of this discussion, attention will be confined to some of the more typical types in the under 50 hp range, which applies to the majority of machine applications.

Standard total speed ratios of these smaller units vary from 1:1 to about 17:1, providing either or both speed increase or reduction and, in some cases, reverse. Speed control may be by lever, *Fig*. 17 or by handwheel, *Fig*. 18. Typical speed ratios provided by a 4-speed unit of the type shown in *Fig*. 18 are 3.25:1, 2.17:1, 1.5:1 and 1:1 Various shaft and mounting arrangements are possible to suit different application or input power arrangements.

These units are advantageous from the standpoint of installation convenience, eliminating the need for overhead line shafts and long belts. Machine portability is thus increased and operator convenience improved. Usually, power is supplied through a V-belt drive and offers some flexibility in adjusting final speeds. In all these gear transmissions, when either input or output shafts are not connected directly to the prime mover or driven machine, overhung loads must be taken into account.

Where space limitations or appearance considerations are important, motorized units offer a compact and efficient adjustable-speed power package, *Fig*. 19. Standard designs have been developed in a number of transmission sizes, matched to different heavy duty induction motor ratings, to meet machine requirements in capacities of from fractional to 15 hp. Rated horsepower is developed at all speeds and up to eight different speed selections are possible when two-speed motors are utilized. Typical speed ratios supplied by a four-speed unit are 4.15:1, 3.15:1, 1.85:1 and 1:1. Here also, several mounting and shaft arrangements are possible. The constant-horsepower characteristic has made these units particularly attractive for applications in machine tools and processing equipment.

Where speed changes are infrequent and horsepower requirements low, units such as shown in *Fig*. 20 may offer cost advantages. Speed adjustment is obtained by varying the sheave combinations on the drive motor and pinion shaft. Capacities range from ¼ to 2 hp and speeds of

1 to 750 rpm can be obtained with a 1725 rpm motor.

Epicyclic Gear Trains: Of growing interest today because of their adaptability to automatic control techniques, epicyclic gear trains offer an almost unlimited variety of possibilities for adjustable-speed control. Basically, an epicyclic train is one in which part of the gears can move relative to a gear with a fixed axis; the gears of the train are always in mesh. Typical examples are the familiar planetary gear sets.

Epicyclic gear systems have been widely used in automotive and aircraft drive applications. For example, all present automatic automotive transmissions, even those of the torque converter type, employ some form of epicyclic gearing to provide additional drive ratios, *Fig.* 21.

Planetary gearing and its many practical aspects have been treated in detail elsewhere in the literature. In this discussion, only the highlights and some of the more recent innovations with regard to speed adjustment techniques will be covered.

In a simple system of planetary gearing, *Fig.* 22, four methods of speed control are possible:

1. Ring gear stationary, sun gear driving. Planet carrier moves in same direction as sun gear.
2. Sun gear stationary, ring gear driving. Planet carrier moves in same direction as the ring gear.
3. Planet carrier stationary. Sun gear and ring gear rotate in opposite directions.

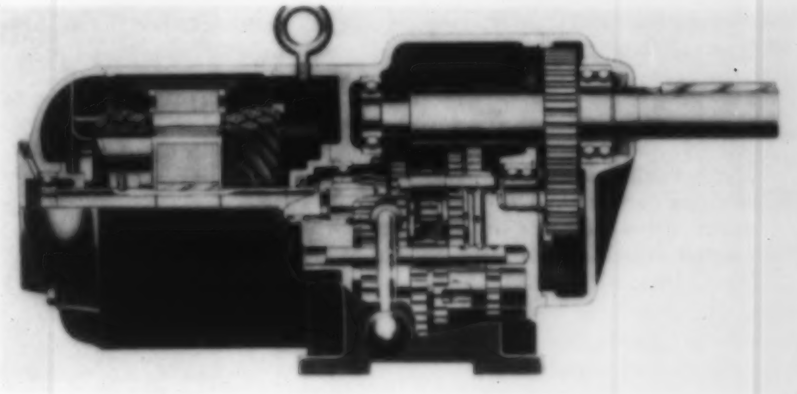


Fig. 19—Packaged gear drive with four-speed transmission and motor mounted integrally. Photo, courtesy Lima Electric Motor Co.

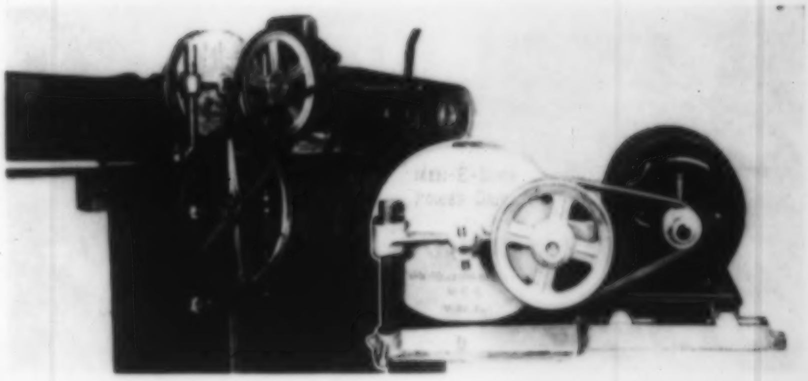


Fig. 20—Low-power gear unit designed to facilitate rapid sheave changeovers where speed changes are infrequent. Photos, courtesy New Standard Div., U. S. Expansion Bolt Co.

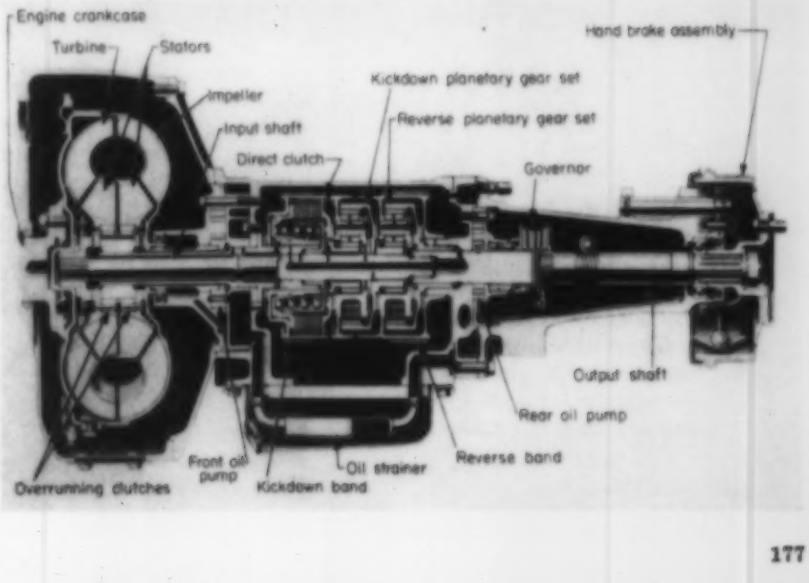

Engine crankcase
Turbine
Stators
Impeller
Input shaft
Direct clutch
Kickdown planetary gear set
Reverse planetary gear set
Hand brake assembly
Governor
Output shaft
Rear oil pump
Reverse band
Oil strainer
Kickdown band
Front oil pump
Overrunning clutches

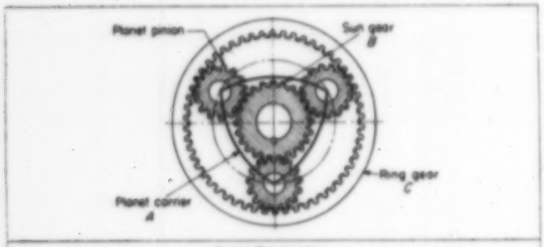
Fig. 21—Powerflite automatic transmission with torque converter and two-speed planetary gear box to increase ratios in low range and facilitate reversing. Photo, courtesy Chrysler Corp.

4. Any two members locked together. Planetary train functions as a coupling and all members rotate as a unit.

The first two conditions always produce a speed reduction. The third condition provides a reversing drive, with a speed increase if the ring gear is driving, a speed decrease if the sun gear is driving. Under the last condition, a direct drive results.

In converting a simple planetary train into a multispeed transmission, auxiliary clutching and braking means, or other similar equipment, are required to control operating conditions. As a result, planetary transmissions run relatively high on the cost scale as compared to other methods of speed adjustment. For a given ratio range and

Fig. 22—Basic planetary gear system in which speed relationships are controlled by holding different members stationary



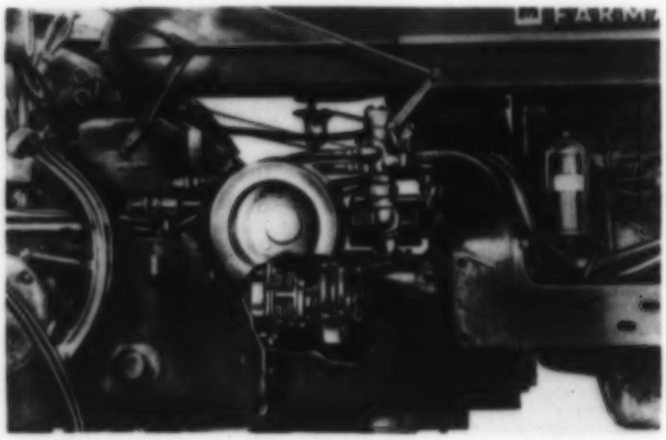
Speed Relationships

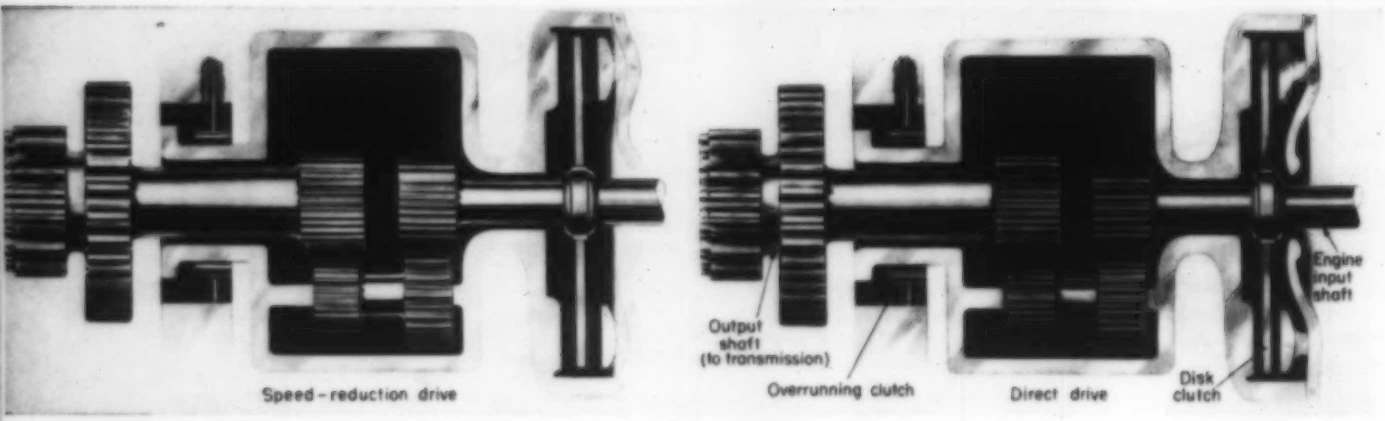
N = speed, rpm

d = number of teeth

Input member	Stationary member	Output member	Speed ratio
Sun gear	Ring gear	Planet carrier	$N_B/N_A = 1 + d_C/d_B$
Ring gear	Sun gear	Planet carrier	$N_C/N_A = 1 + d_B/d_C$
Sun gear	Planet carrier	Ring gear (reverse)	$N_B/N_C = -d_C/d_B$

Fig. 23—Right and Below—Planetary gear torque-amplifier unit employed with standard five-speed transmissions on Farmall and McCormick tractors. Unit is controlled by two-position manual lever and permits step-down speed changes in any gear without manual clutching or interruption of power flow. Photos, courtesy International Harvester Co.





Speed-reduction drive

Direct drive

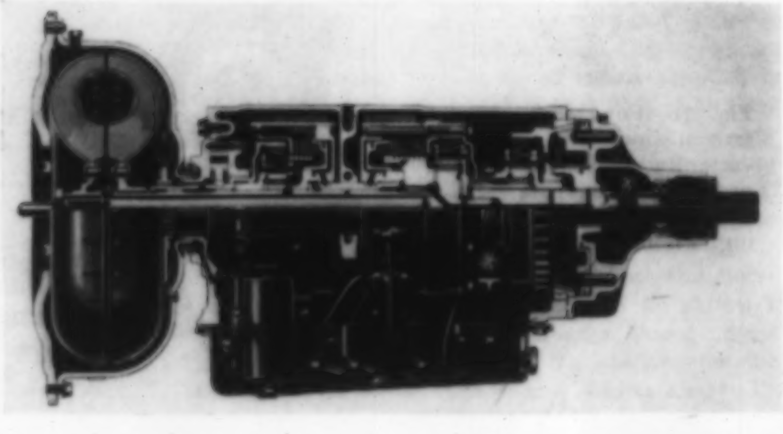


Fig. 24—Hydra-Matic transmission containing three planetary gear units in tandem for automatic shifting. Photo, courtesy Detroit Transmission Div., General Motors Corp.

torque capacity, the planetary transmission offers the most compact gear arrangement of any of the gear units. It can be made to operate quietly and produce high efficiency. However, as the number of speeds increase, the necessary control arrangements may approach the point where they take as much space as the gears and involve a complex combination of mechanical, hydraulic, pneumatic or electric devices and connections. Also practical ratios possible with planetary sets are limited. Bearing supports are often a problem. However, the control and operating characteristics, as well as the compactness of the planetary design, often justify the added expense for certain applications.

A two-speed planetary transmission can often be used to advantage with a selective-speed gear transmission, *Fig*. 23, to provide step-down speed changes under full load and power. Installed on either the input or output end of the main transmission, the planetary unit can be controlled through a manual lever, or some type of automatic device, to furnish instantaneous speed reductions or thrust boosts to meet load requirements.

In the Hydra-Matic transmission, *Fig*. 24, which has been widely used on passenger automobiles and other vehicles, automatic shifting through several different drive ratios is obtained with three simple planetary gear units, of different gear reduction, mounted in tandem. Four forward speeds are provided by the front two units and reverse by a third gear set at the rear of the transmission. Power from the engine enters at the ring gear of the front unit, which acts as a speed reducer when the sun gear is held stationary by a band brake. Output power leaves via the planet carrier and is transmitted through a fluid coupling to the sun gear of the second planetary unit. This unit also acts as a reduction drive, with a greater ratio than the front unit, when the ring gear is braked. Final power-take-off is through the planet carrier of the second gear set. Disk clutches permit each of the planetary units to be individually "locked-up" in direct drive. Operation of the brakes and clutches is controlled automatically through a hydraulic servo system which is responsive to both vehicle speed and throttle position. In first speed, both planetary units are in reduction drive. In second speed, the front unit is in direct drive, the back unit in reduction. Third speed is obtained with the front unit in reduction drive, the back unit in direct drive. For fourth speed, both units are locked in direct drive. Typical ratios obtained are, going from first to fourth speeds, 4.1:1, 2.6:1, 1.55:1 and 1:1.

In reverse, the ring gear of the third planetary unit is held stationary by a hydraulically actuated cone clutch and both the brake and clutch on the second unit are released, other conditions being the same as for third speed. With this arrangement a compound reduction action is produced through the second and third planetary gear sets (4.62:1), reversing the direction of rotation of the output shaft.

Although comparatively complex and high in cost when combined with a hydraulic servo system for automatic speed control, this type of transmission has proved practical and reliable in service. The same principles could be applied to the design of transmissions of almost any drive ratio range. Number and size of the planetary gear units and control devices would be a function of the total speed ratio range and the frequency of intermediate power "steps."

Additional flexibility in speed adjustment with planetary gearing is offered by the compound planetary systems, *Fig*. 25. The extra gears increase the number of output speeds possible. In the compound internal-external unit, *Fig*. *25a*, two sun and two ring gears permit a selection of several output speeds, either from the planet carrier or from one of the ring or sun gears. Idler gears can be incorporated to aid reversing, *Fig*. 25*b*. This last design has been used to advantage in automatic automotive transmissions of the fluid torque converter type to increase ratios in the low range and provide a means for reversing. A great many variations are possible.

Planetary gearing is also employed in a number of "differential" drives. In these applications, two of the planetary members are driven by separate input sources and the difference or sum is transmitted by the third member to a single out-

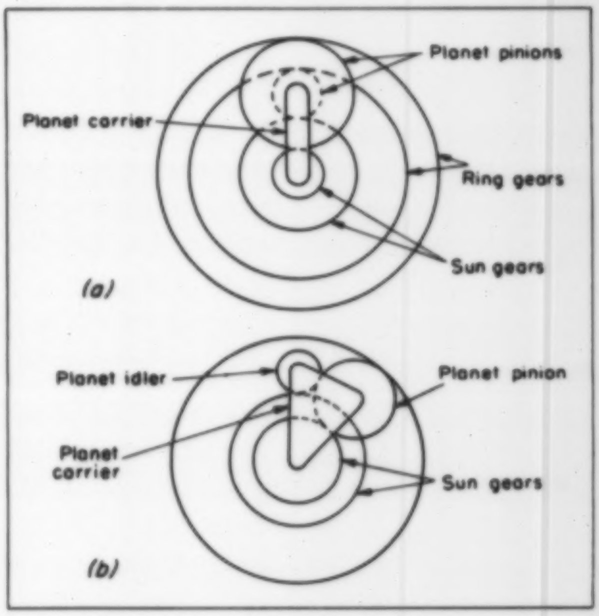


Fig. 25—Two compound planetary gear systems showing, *a*, internal-external type and, *b*, internal-external type with idler planet pinion

put shaft. Stepless speed adjustment devices of both the limited and infinite range types have made use of this principle. Practical application aspects will be discussed later in these articles.

Calculation of speed and torque relationships in planetary gear systems, although numerically simple, can be full of traps if care is not exercised in design analysis. The subject has been treated extensively in the literature and several excellent basic references are available.

Stepless Speed Adjustment—Limited Range

For any adjustable-speed drive, quality of performance is dependent on the degree to which machine operating speeds can be matched to load requirements. In some cases, only a fixed number of speeds in discrete steps will be satisfactory but in many applications infinite or stepless variation over a specific speed range is both desired and necessary. Even in the automotive fields where multispeed gear transmissions have been predominant, a transmission of infinitely variable ratio has long been the ideal; several promising designs of the all-metal traction type have been proposed but, as yet, none have been put into service.

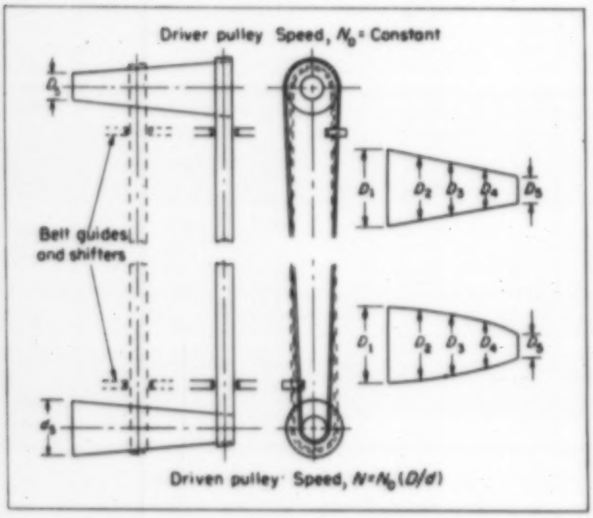
Stepless speed adjustment can be obtained mechanically in a number of ways. The principles are well known and, as a rule, the various speed changing devices that have been developed represent a compromise of design and operating principles of mechanical drives of the fixed ratio type. Limited range units will be discussed first. A succeeding section will consider the infinite range types.

In general, these mechanical systems are the most economical to use. First costs are usually lower than for other comparable systems within their range and, because of their inherent simplicity of construction, they are easier to operate and maintain. At the same time, output torque ratings are limited by the strength, wear or operating characteristics of the speed-adjusting mechanism. This condition places a rigid limitation on horsepower capacity at low speed which, in turn, determines the size of the speed mechanism and, of course, of the overall unit.

Cone Pulleys: Often referred to as the basic system of stepless speed control, cone pulleys or speed cones, *Fig.* 26, are essentially an evolution of the stepped pulley systems discussed earlier. In these pulleys, the steps are infinitely small and the working surfaces take the shape of frustums of cones. Power is transferred by an endless flat belt, and stepless speed adjustment is obtained by shifting the belt back and forth along the pulleys.

Working diameters are measured at the center of the belt and slipping is inherent since contact surface speed varies across the belt face. Belt guides, which move simultaneously when the belt is adjusted, are necessary near the point of contact with each pulley; otherwise, the belt will tend to climb toward the large end of each cone surface.

Speed settings are unstable and power losses are high due to belt slip and creep. In theory, there should be only line contact and, thus, belt widths must be kept to a minimum, reducing power transmitting capacity. Belt life is short and



Driver pulley Speed, N_D = Constant
d_5
D_1
D_2
D_3
D_4
D_5
Belt guides and shifters
d_5
Driven pulley Speed, $N = N_D(D/d)$

Fig. 26—Typical cone pulley system for stepless speed control in flat-belt drives

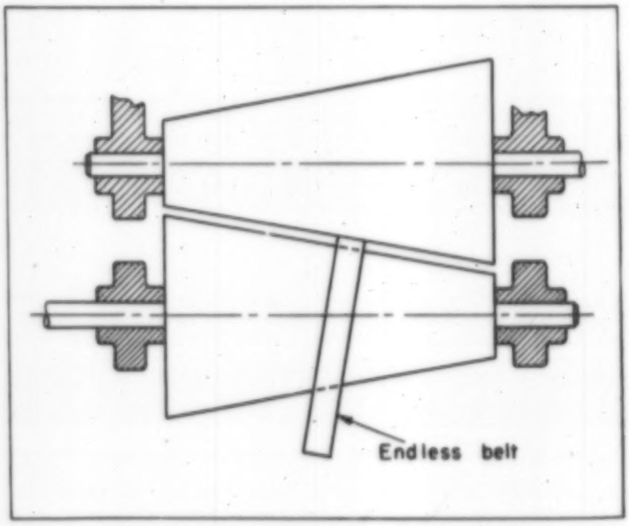


Fig. 27—Friction cones engaging an adjustable leather belt which controls speed ratio

wear is a problem. To design a pair of symmetrical cone pulleys, a series of diameters are calculated in the same manner as for the stepped pulleys. The diameters are then plotted at equal distances apart and the end points joined by a smooth line. Contours may be straight lines or curves.

An interesting modification of the cone pulleys is the friction cone arrangement shown in *Fig*. 27. Power is transmitted through an endless narrow belt running between the cones, which are spring-loaded to maintain proper contact pressures. Speed is adjusted by moving the belt back and forth. Although slippage is also inherent in this device, the design does mitigate some of the drawbacks of the speed cones.

In the form shown, the friction cones rotate in opposite directions. If a wheel is substituted for the belt, the same speed variation is possible with the cones rotating in the same direction.

Variable-Pitch Pulley Systems: Despite the crudeness and shortcomings of the early cone pulley systems, the principle is the basis for most of present commercial mechanical systems for stepless speed adjustment. Speed adjustment is obtained through the use of pulleys or sheaves, with sliding cone faces, in which the operating pitch diameter can be changed. Power is transmitted by means of some form of belting.

Typical systems vary from the simple variable-pitch V-belt sheave on a motor with an adjustable base, *Fig*. 28, to package transmission units employing special types of "belts," *Fig*. 29. How these units are used and the different commercial types available will be evident from the following discussion.

Variable-Pitch Sheaves: Reliable and inexpensive, variable-pitch sheaves have long been popular as a method of speed adjustment. Usually, they are a part of a drive assembly that includes an adjustable motor base, V-belts and a companion sheave.

When speed changes are infrequent and the drive can be stopped for speed adjustment, one of the stationary control types may often be the best and most economical solution. These sheaves are also useful when the exact operating speed of a machine cannot be predetermined. Installing a sheave that covers the range of possible variation permits exact adjustment of the operating speed at the point of final installation. Ventilating fans and spinning frames are typical of such applications. Another possible application, of a similar nature, is in the drives of machines equipped with stepped speed devices where fine speed adjustments may be desirable.

Stationary-control sheaves are available in single and multiple groove (up to 12) sizes for all standard V-belt sections up to E and in capacities from fractional to 300 hp, *Fig*. 30. Pitch diameters are fairly well standardized and range from a minimum of 1.9 inches (A-belt) to a maximum of 23.75 inches (E belt). Standard companion sheaves are available in diameters of 2.2 to 48 inches. Cast iron, pressed steel or die-cast constructions are used.

Depending on diameter and belt section, speed variations to about 50 per cent can be obtained

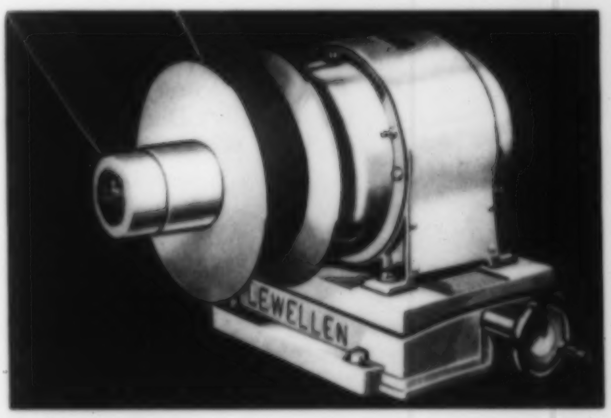


Fig. 28 — Above — Simple mechanical adjustable-speed system employing a variable-pitch sheave and a motor with an adjustable base. Photo, courtesy Lewellen Mfg. Co.

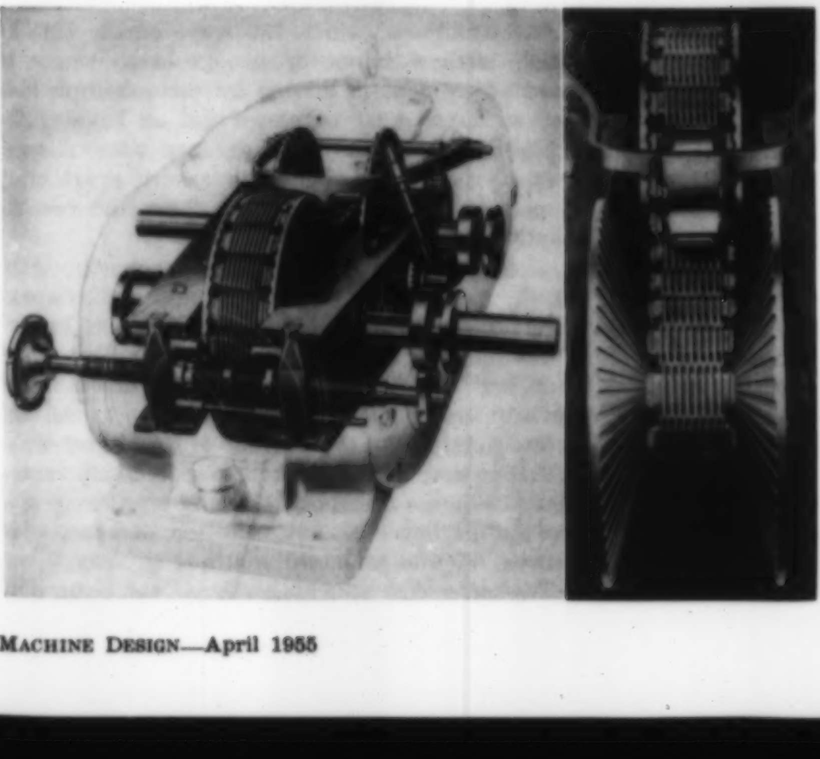


Fig. 29 — Left — All-metal transmission design which has a self-forming laminated steel belt and variable-pitch "sprocket" pulleys. Pitch diameters of pulleys, and speed, are controlled through a positive linkage system. Photo, courtesy Link-Belt Co.

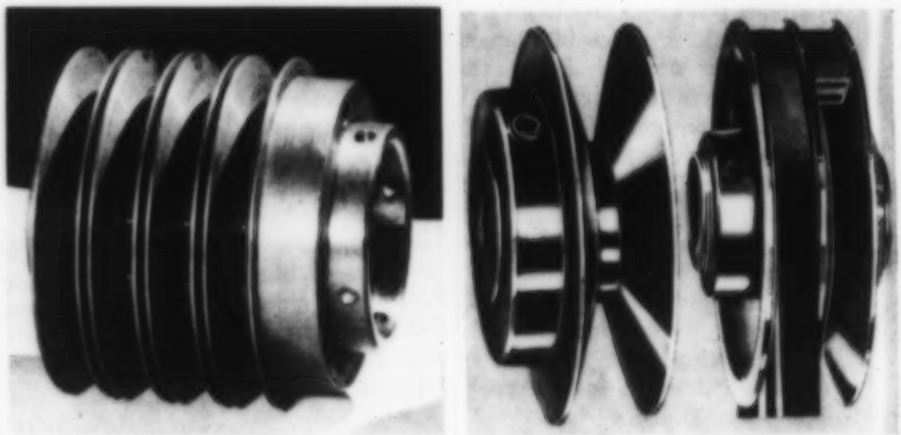


Fig. 30—Typical stationary-control sheaves for use with standard V-belts. Photos, courtesy (left) Allis-Chalmers Mfg. Co. and (right) American Pulley Co.

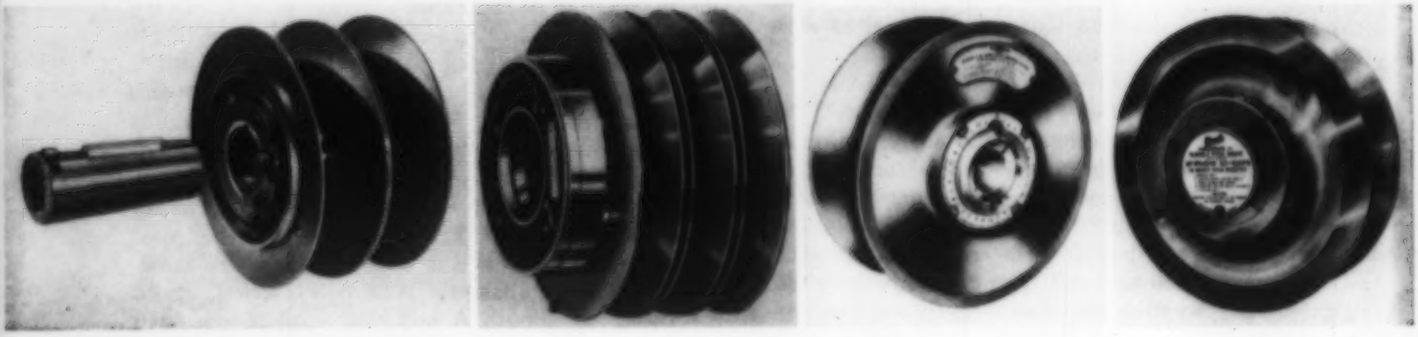


Fig. 31—Typical stationary-control sheaves for use with wide-range Q, R, and W V-belts. Photos, courtesy (left) Allis-Chalmers Mfg. Co., (left center) American Pulley Co., (right center) Dodge Mfg. Corp. and (right) T. B. Wood's Sons Co.

when a fixed ratio companion sheave is used. In the higher horsepower capacities this range will be somewhat less, usually under 30 per cent. Some means of take-up must be provided in the drive assembly for adjustments in center distance to accommodate normal belt stretch and changes in pitch diameter. If constant center distance is a requirement, a combination of two variable-pitch sheaves may be a possibility, giving added flexibility in both takeup and speed adjustment. However, expense and adjustment problems increase accordingly and diameter limitations of available sizes may not permit desired speed values to be achieved. A more practical tensioning arrangement is obtained by employing a spring-loaded flat face idler pulley on the bottom of the belts.

Where a wider range of speed variation is required, ratios up to 3:1 are possible with a group of stationary control sheaves designed for use with the wider and thinner Q, R and W section V-belts, *Fig.* 31. Both single and multiple-groove (up to four) sizes are available in capacities from 1½ to 30 hp. Pitch diameters vary from a minimum of 3.5 to a maximum of 12.9 inches. Matching companion sheave diameters range from 6 to 40 inches. As a result of the wider speed ranges, center distance variations may necessitate special motor bases for adequate take-up allowance.

Within their range, stationary-control sheaves offer a high degree of speed control at low cost. Since the parts are locked during operation, wear and lubrication are not problems. Construction details vary with the manufacturer and have a bearing on cost.

In the stationary-control sheaves, speed adjustment is usually obtained in two ways: (1) Flanges are mounted on threaded hubs and locked in place by set screws or (2) flange position is controlled by some form of tie bolt or stud arrangement with provision for external wrench adjustments. In the first case, which fits some of the smaller sheave sizes with one or two grooves, degree of speed adjustment is limited by the condition that the set screw must engage a flat or keyway for locking. Also, in the double-groove sizes, flanges must be carefully adjusted to assure equal pitch diameters. On the other hand, these sheaves are usually the lowest in cost.

Another point to consider is the manner in which the flanges move. In some types, both flanges move together, maintaining belt alignment. In other designs, one flange is stationary and misalignment will occur during adjustment unless some provision is made to simultaneously move the motor. Admittedly, the amount of misalignment is small but may reduce belt life appreciably where center distances are short. Misalignment may also have an influence on the selection of companion sheaves. While standard multiple groove V-belt sheaves offer cost advantages, groove spacing may

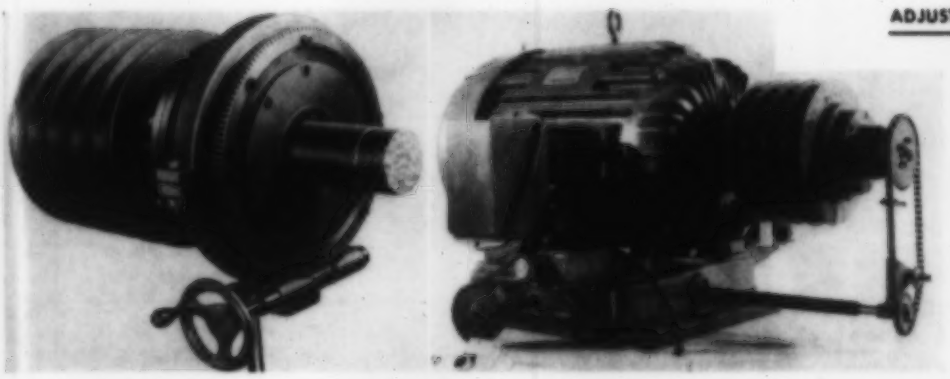


Fig. 32 — Left — Typical multigroove motion-control sheaves for accurate speed adjustment over narrow range. Photos, courtesy Allis-Chalmers Mfg. Co.

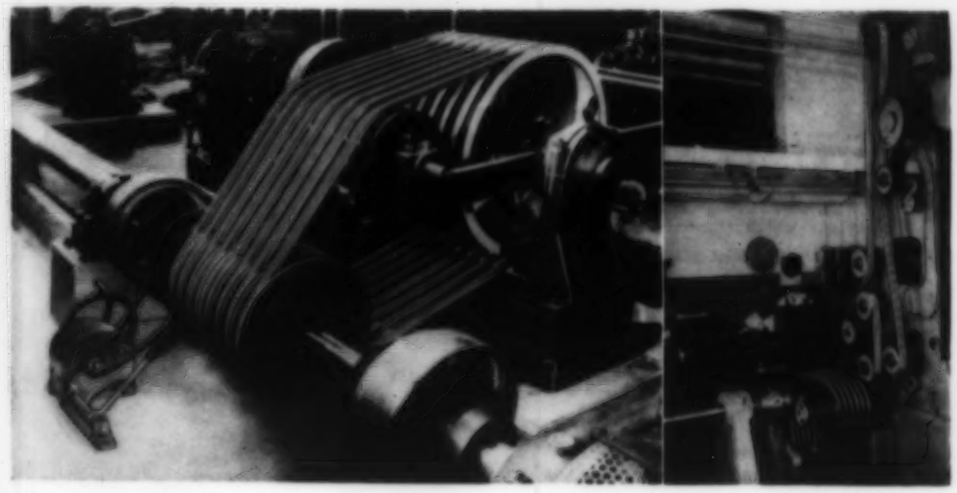


Fig. 33—Heavy-duty applications of multigroove motion-control sheaves in, left, Standard Fourdrinier paper machine and, right, Langston slitter and winder. Belt tension is controlled by idler pulleys. Photos, courtesy Allis-Chalmers Mfg. Co.

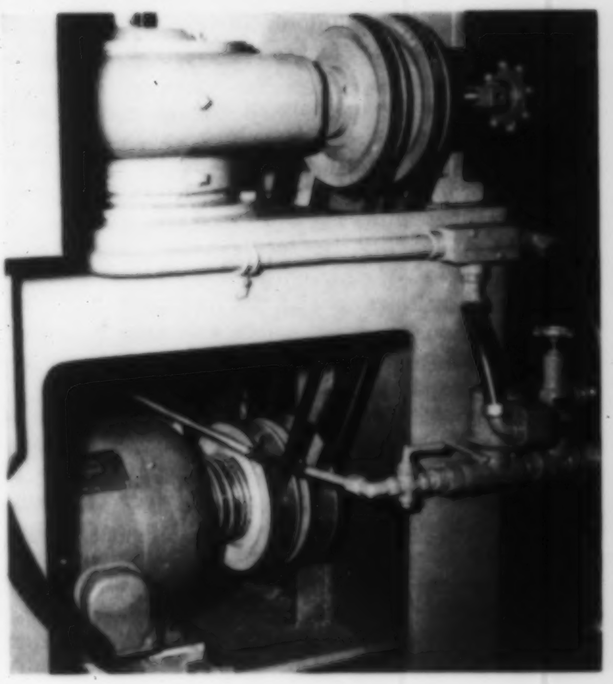


Fig. 34—Below—Built-in drive assembly using spring-loaded and adjustable double-groove variable-pitch sheaves for speed control. Photo, courtesy Speed Selector Inc.

not be satisfactory and special companion sheaves designed for adjustable-speed applications may be necessary. In each application, the variables of cost and operating characteristics have to be juggled according to design objectives. Rules of standard V-belt practice will apply in all cases.

When speed changes are frequent and/or must be made with the drive in operation, an adjustable-speed system of the motion-control type is necessary. A number of variable-pitch sheave designs are available. On the basis of general industrial usage, they are the most popular and widely used method of speed control. As compared to stationary-control sheaves, they require more attention in the way of lubrication and maintenance and usually run higher in first cost. However, within their range of application, they are generally the most practical and economical means of speed adjustment.

Most of the commercially available sheaves fall within the fractional to 15-hp capacity range with speed ratios up to 4:1. However, where close control of speed over a narrow range is important, a series of multiple-groove motion-control sheaves offers capacities of from 1 to 300 hp, *Fig.* 32. Essentially modified stationary-control sheaves, these units provide speed variations averaging about 25 per cent per sheave and take all standard A to E V-belt sections. Available sizes run approximately the same as for the corresponding stationary-control types. Various control arrangements are possible to fit special conditions, *Figs.* 32 and 33. Flat-faced idler pulleys operating under spring-loading are recommended for maintaining tension when constant center distance is a requirement.

The simplest and most widely used motion-control systems are typified by the arrangement shown in *Fig.* 28. The conventional drive assembly consists of a motor mounted on an adjustable base, a vari-

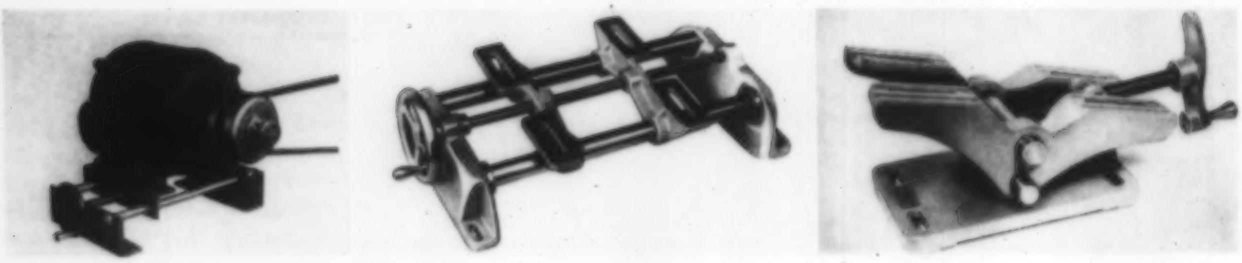


Fig. 35—Above—Typical sliding and tilting motor base designs with handwheel adjustment of motor position. Photos, courtesy (left) Equipment Engineering Co. and (center, right) Lovejoy Flexible Coupling Co.

able-pitch sheave with spring-loaded flanges and a companion sheave or pulley which is driven by some form of V-belt. Speed is adjusted while the drive is in operation by shifting the motor back and forth on its base. This action alters the center distance and forces the spring-loaded sheave flanges to move in and out as belt tension changes, thus varying the pitch diameter and the speed ratio. A variety of commercial sheave designs of this type are available in capacities from fractional to 15 hp with speed ratios up to 4:1. Depending on the manufacturer, either standard or nonstandard V-belts may be used. Most designs are of the single-groove type; however, double-groove sizes are also being used, *Fig.* 34. Sheave flanges may be plastic, cast iron, or steel.

Motor bases are usually of the tilting, or sliding types, *Fig.* 35, with handwheel adjustment. Where final driven speeds drop below the limitations of standard sheave combinations, countershaft arrangements, *Figs.* 36 and 37, or gear reducers may readily be incorporated to increase flexibility, *Fig.* 38. An unusual double-sheave arrangement is shown in *Fig.* 39. A number of control arrangements are possible and may be either manual, semiautomatic or automatic. Typical applications are shown in *Figs.* 40 and 41.

Sheave construction details vary with the manufacturer and the horsepower size, but certain general features are worthy of consideration. As in the stationary-control types, the manner of flange movement may be an important performance factor. When only one moving flange is used to change pitch diameters, misalignment may be appreciable due to the wide speed ranges involved. It may be necessary to use an "angled" motor base design to compensate for the belt shifts. Another solution, although perhaps not as satisfactory, is the use of a crown or flat face driven pulley which permits the belt to shift sideways to compensate for changes in flange position.

To obtain the maximum speed range possible with standard V-belts, some of the sheave designs employ cut-outs in the flange faces to increase flange movement. The interrupted surfaces tend to increase belt wear and noise but are often justi-

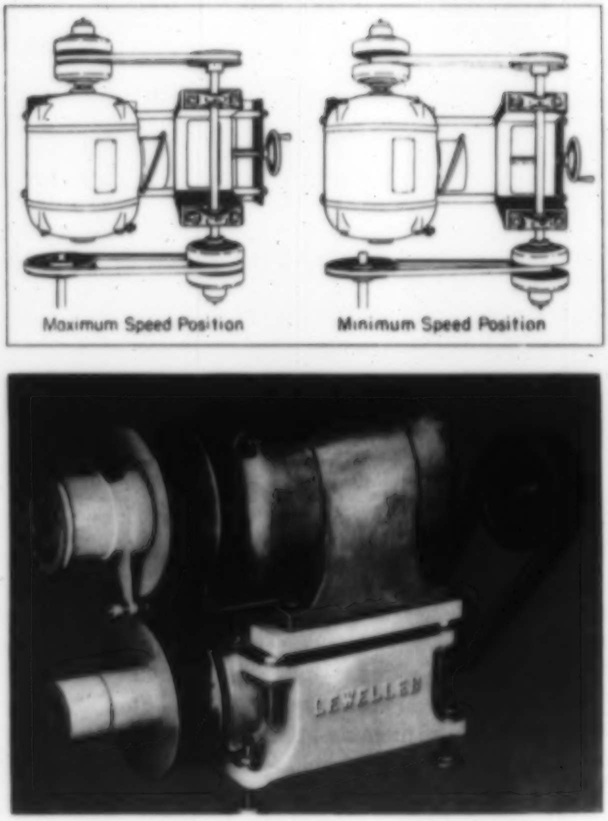


Fig. 36—Two typical countershaft systems for reducing output speeds and increasing speed range. Speed is controlled, bottom, by adjustable-pitch sheave on motor and, top, by movable countershaft. Sketch courtesy Equipment Engineering Co.; photo, courtesy Lewellen Mfg. Co.

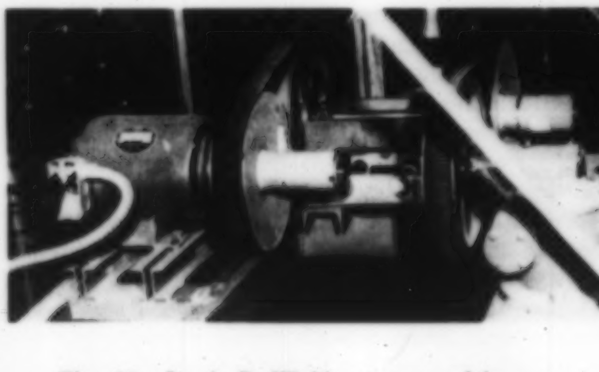


Fig. 37—Jervis B. Webb conveyor drive using two variable-pitch sheaves in a countershaft arrangement to produce 9:1 speed variation. Photo, courtesy Gerbing Mfg. Co.

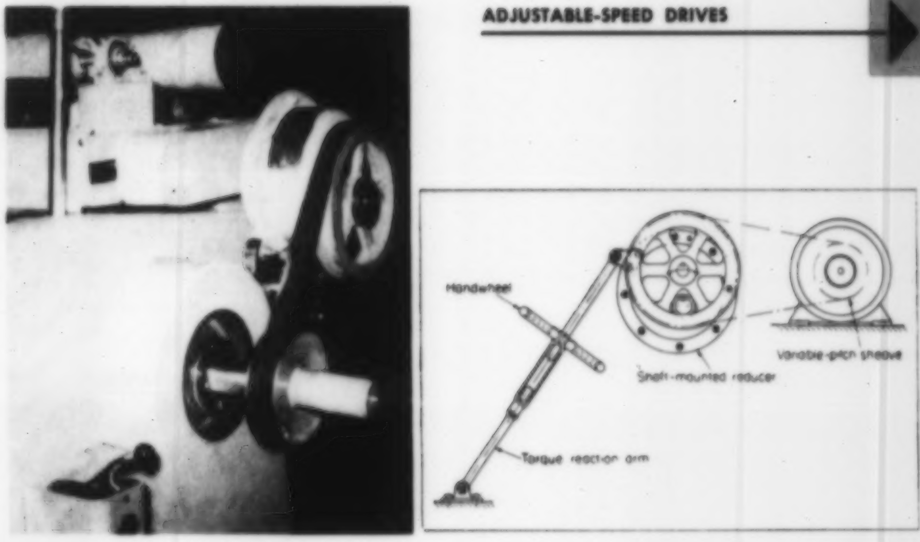


Fig. 38—Wicklander belt sander employing shaft-mounted speed reducer and variable-pitch sheave in combination to produce low-output speeds with 3:1 range. Schematic drawing shows typical drive assembly with handwheel control of gear reducer position and speed. Photo, courtesy Gerbing Mfg. Co.; drawing, courtesy Falk Corp.

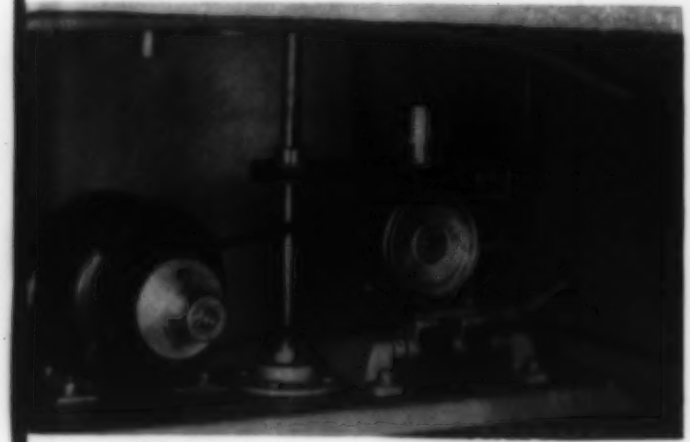


Fig. 39 — Plate whirler drive containing two variable-pitch sheaves in a right-angle arrangement for 8:1 speed variation. Speed is controlled by adjusting position of right-angle gear unit on its movable base. Photo, courtesy Gerbing Mfg. Co.

Fig. 40—Reaming and tapping machine showing simple built-in variable-pitch sheave drive with handwheel speed adjustment. Photo, courtesy Reeves Pulley Co.

fied by the cost benefits realized.

Performance of these types of sheaves is influenced by a number of variables. Changes in transmitted torque or input speed cause variations in speed ratio due to spring action, slippage, and tendency of belts to move in or out under load fluctuations. Pressure of the flange faces against the belt decrease as the working pitch diameter increases. As a result of these and other variables, degree of speed control and efficiency are limited but are usually sufficient for most general purpose applications.

As a general case, most manufacturers conservatively rate their sheaves on a constant-torque basis, with horsepower capacity decreasing as speed decreases. Actually, as is true of most mechanical units, these devices are fundamentally torque converters. The purpose of these ratings is to add a margin of protection against excessive and unpredictable load conditions. For example, a typical basis of the ratings is that they be "sufficiently conservative to handle the normal running overloading of a standard squirrel-cage induction motor without undue belt slippage."

If constant center distance is a requirement or a wide range of speed variation is desired, two variable-pitch sheaves may be used in combination, *Fig.* 42. In this arrangement, one of the sheaves has spring-loaded flanges while the other incorporates some means for controlled adjustment of pitch diameter. Flange movements are co-ordinated to maintain belt alignment. Speed ratios up to 10:1 are possible and speed range may be changed by varying the center distance with belt length constant. Horsepower capacities are, of course, subject to the limitations of the spring-loaded sheave designs. Manual or automatic-control arrangements are equally feasible.

Compound Floating Sheaves: Another method of obtaining a wide range of speed variation employs a compound variable-pitch sheave assembly mounted on an intermediate countershaft between the driving and driven shafts. The assembly consists essentially of two variable pitch sheaves mounted side by side with a center floating flange member, either divided, *Fig.* 43, or common to both *Fig.* 44. Distance between the outer flanges is fixed. Separate belts connect the compound sheaves with fixed-pitch driving and driven sheaves, which are mounted at a constant center distance. The countershaft is carried on a swinging arm so that the center distances between it and the driving and driven shafts may be varied. Speed is usually varied by changing the position of the countershaft, causing the floating member to shift back and forth under belt pressure and vary the pitch diameters of the compound pulleys, *Fig.* 45.

Speed ratios to 10:1 can be obtained and commercial units are available in capacities from fractional to 10 hp, although widest application has been in the low horsepower range under 5 hp. Most of the units take standard V-belt sizes and flanges may be plastic, aluminum, or die cast.

If still higher speed ratios are desired, two

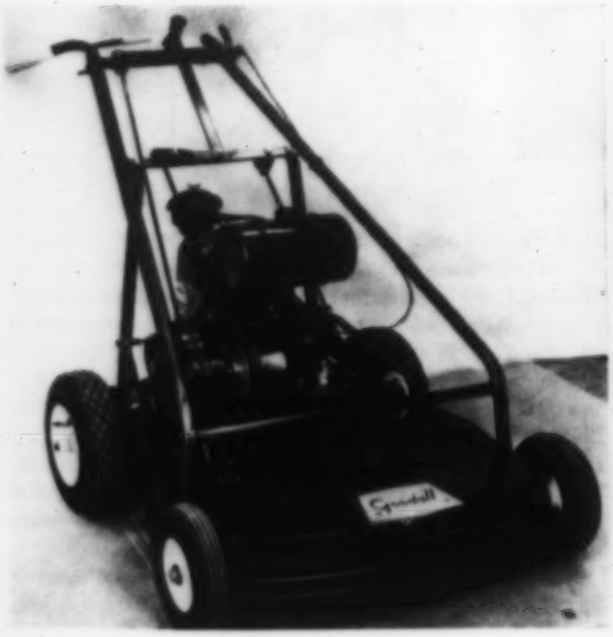


Fig. 41—Goodall lawnmower using a variable-pitch sheave with standard A belts. Speed is remotely controlled through a linkage system which permits adjustment of a pivoted idler sheave. Photo, courtesy Lovejoy Flexible Coupling Co.

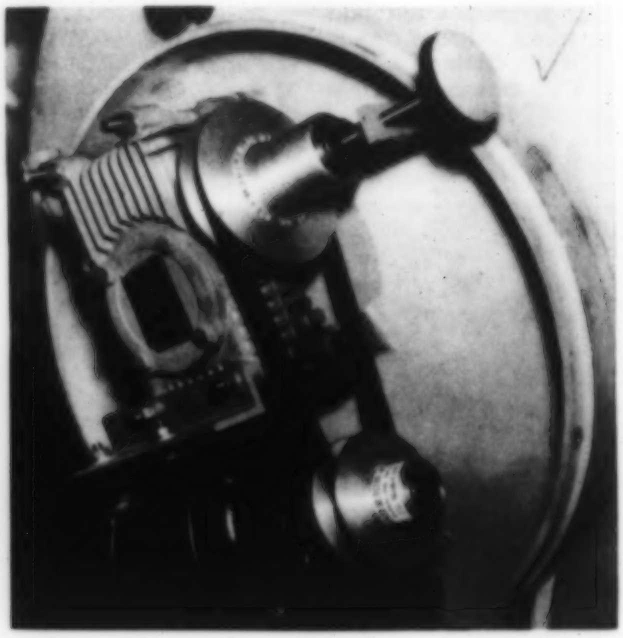


Fig. 42—Spring-loaded variable-pitch sheave on motor driving to adjustable-diameter sheave on gear box for bottle-capping machine. Speed ratios up to 10:1 are possible with this type of combination drive which operates at constant center distance. Photo, courtesy Speed Selector Inc.

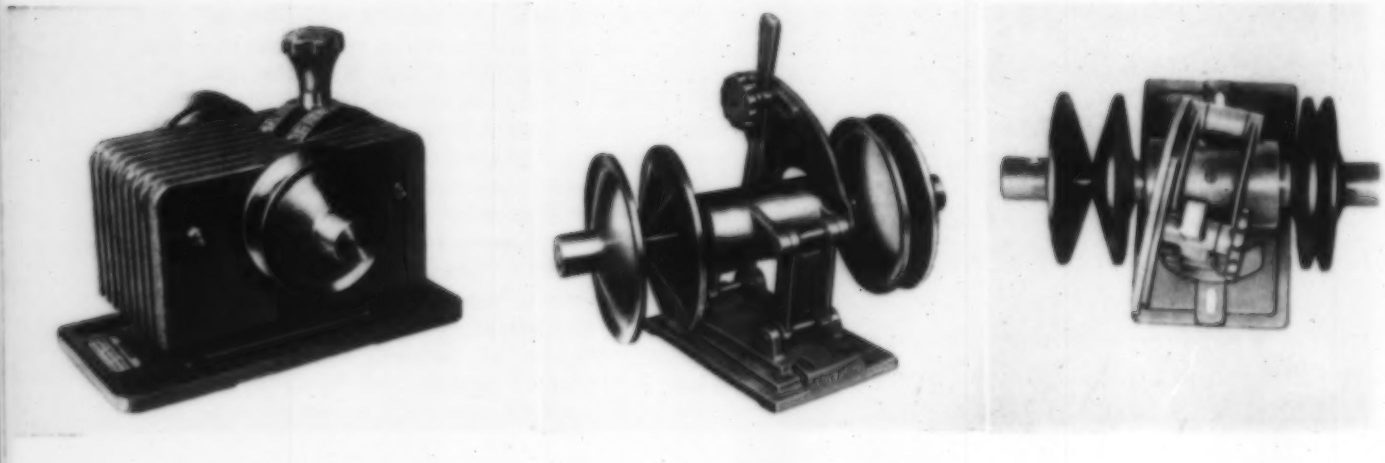


Fig. 43—Typical compound floating sheaves with divided floating center flanges. Photos, courtesy (left, center) Lovejoy Flexible Coupling Co. and (right) Standard Transmission Equipment Co.

countershaft sheave sets can be employed in series; however, horsepower capacity will be considerably reduced. Maximum and minimum output speeds are determined by the sizes of the fixed ratio sheaves on the driving and driven shafts. Speed variation is provided in equal ratios above and below the speed which could be obtained with fixed ratio sheaves alone. Since the sizes of the fixed ratio sheaves do not affect the speed change ratio of the compound sheaves, high flexibility in meeting application requirements is provided. Much lower speeds can be achieved than with the two sheave arrangement, *Fig*. 42, which is usually limited to a minimum of about 300 rpm.

The countershaft units are particularly suited to built-in machine applications, *Figs*. 45 and 46, and offer a relatively economical and compact method of achieving wide speed variation. Recommended practice for best operation is to mount the countershaft in a direct line between driving and driven shafts.

The same principle has been applied in slightly modified form in a unit developed for automatic printing press drives, *Fig*. 47. In this design, the position of the floating flange is positively controlled through a manual knob and the countershaft pivots on an arm to accommodate changes in the pitch diameters. Speed ratios up to 3:1 are achieved in the 1½ to 2-hp range. Successful applications have also been made in a number of drives for different types of processing equipment.

In the past, one of the drawbacks to the compound sheave units has been the comparatively high maintenance costs involved. To always assure equal belt tension and alignment at both sheaves, it is necessary that two paths of motion be provided.

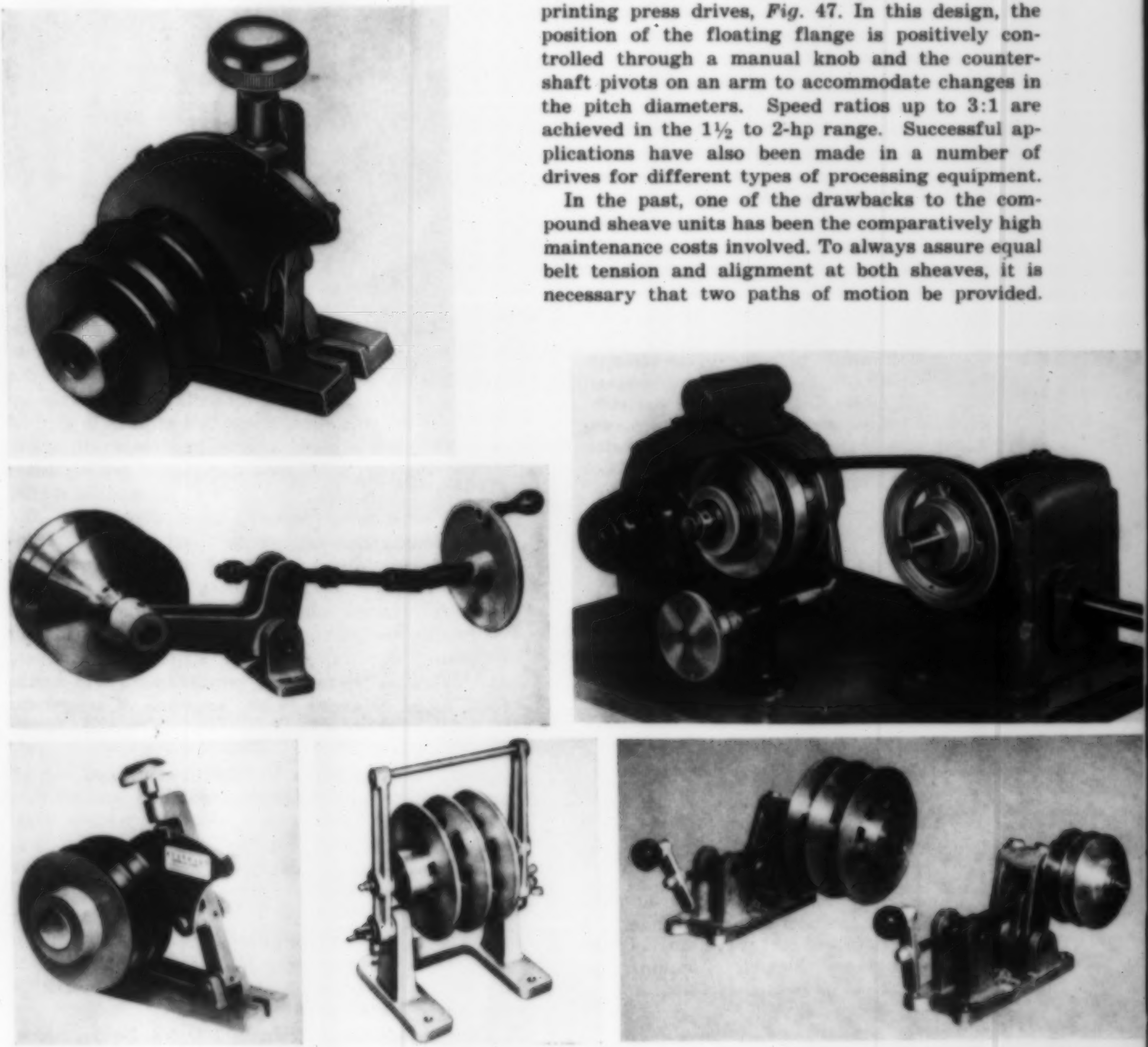


Fig. 44—Typical compound floating sheaves which have a common floating center flange for both sheaves. Photos, courtesy (top left) Lovejoy Flexible Coupling Co., (center left) McLear Transmission Co., (center right) Speed Selector Inc., (lower left) Standard Transmission Equipment Co., (lower center) Toledo Timer Co., and (lower right) Turner Uni-Drive Co.

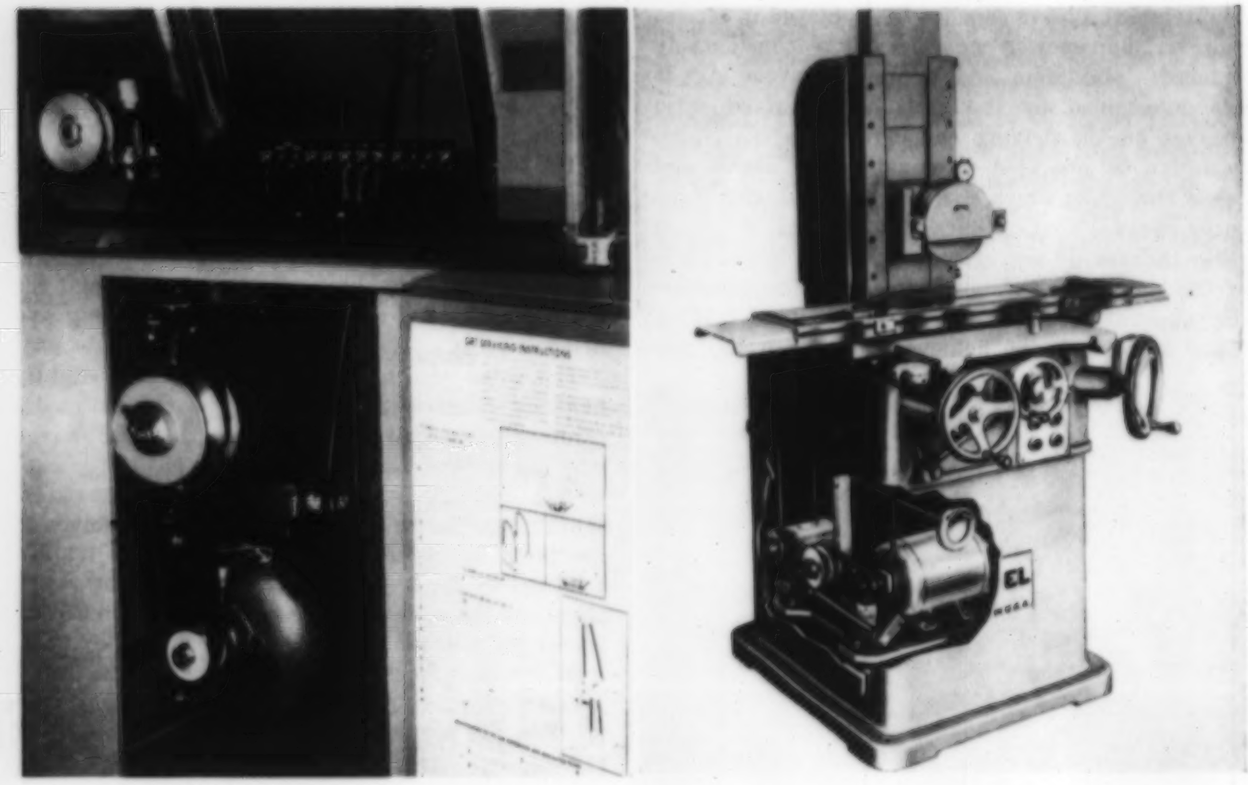


Fig. 45—Sun generator and regulator tester, left, and Covel surface grinder, right, showing built-in drive arrangements with compound floating sheaves. Speed is controlled by pivoting the compound sheave on its swinging arm to vary operating center distances for both belts. Photos, courtesy McLear Transmission Co.

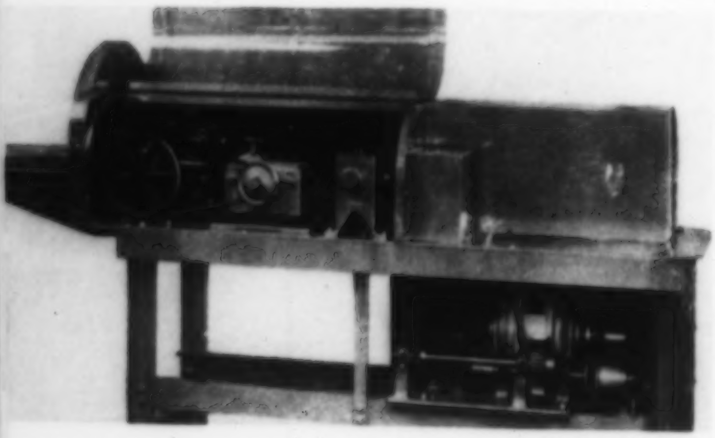


Fig. 46—Lollypop machine with $\frac{1}{2}$-hp drive which uses a compound sheave of divided-flange type to obtain 10:1 speed range. Photo, courtesy Lovejoy Flexible Coupling Co.

For equal belt tension, the countershaft must swing on an arc that is a function of the two belt lengths and the position of the driving and driven shafts. To maintain alignment, the compound sheave outer flanges must move laterally as pitch diameters change. Considerable belt and sheave wear can result if these conditions are not taken into account. Most of the present commercial designs have some form of compensation means built-in. Pivoted motor mounts have also been employed with the weight of the motor hanging on the belts to take up slack. With this method full belt tension is applied at all speeds and motor bounce may cause vibration.

Two recently developed techniques are of interest. In one design, one of the flanges is spring loaded to assure proper tension throughout the speed range with the motor fixed and belt alignment is maintained by means of a cam arrangement. Another method utilizes a linkage arrangement for remote control. Linkage dimensions can be readily varied to suit different speed, load and mounting conditions. Cost, space, performance, and operator convenience requirements will again have to be balanced in the selection of a specific compound pulley unit.

Belt Transmissions: Reliability and accuracy of speed control are distinct attributes of the mechanical belt-type transmissions. Four basic commercial designs are available. Three employ variable-pitch sheaves on parallel shafts and the other utilizes the compound floating-pulley principle. Addition of a power source is all that is necessary to provide a complete drive assembly. Cost and space requirements are primary limitations, but the quality of performance and operating characteristics may often justify application.

Two designs are shown in *Fig.* 48. Both employ special wide V-belts reinforced by wooden blocks and driven by two positively controlled variable-pitch pulleys. Movement of the pulley flanges is synchronized by a linkage arrangement which can be readily adapted to manual, semiautomatic or automatic control means. Construction details vary with the design.

Power capacities from fractional to 87 hp are available and speed ratios to 16:1 are possible in the lower horsepower ranges, dropping to 2:1 in the maximum capacity units. Either shaft may be used for input or output and speed variation ranges above and below the constant input speed. Input speed of these units is limited because of the belt construction and averages around 225 rpm in the high capacities to 625 rpm in the low horsepower units. Some form of accessory drive is usually needed to meet these input conditions. Overhung and thrust loads must also be considered to avoid exceeding bearing capacities when the shafts carry gears, sprockets or pulleys.

Both enclosed and open units are available in a number of horizontal or vertical mounting arrangements, *Fig*. 49, to meet different environmental or space requirements. In addition, for certain capacities the speed-changing mechanism may be obtained separately for building into machines where space is limited. Mechanical, electrical, hydraulic or pneumatic control arrangements are also possible, for both manual and automatic operation.

Applications have been primarily in production machinery where accuracy of speed control and

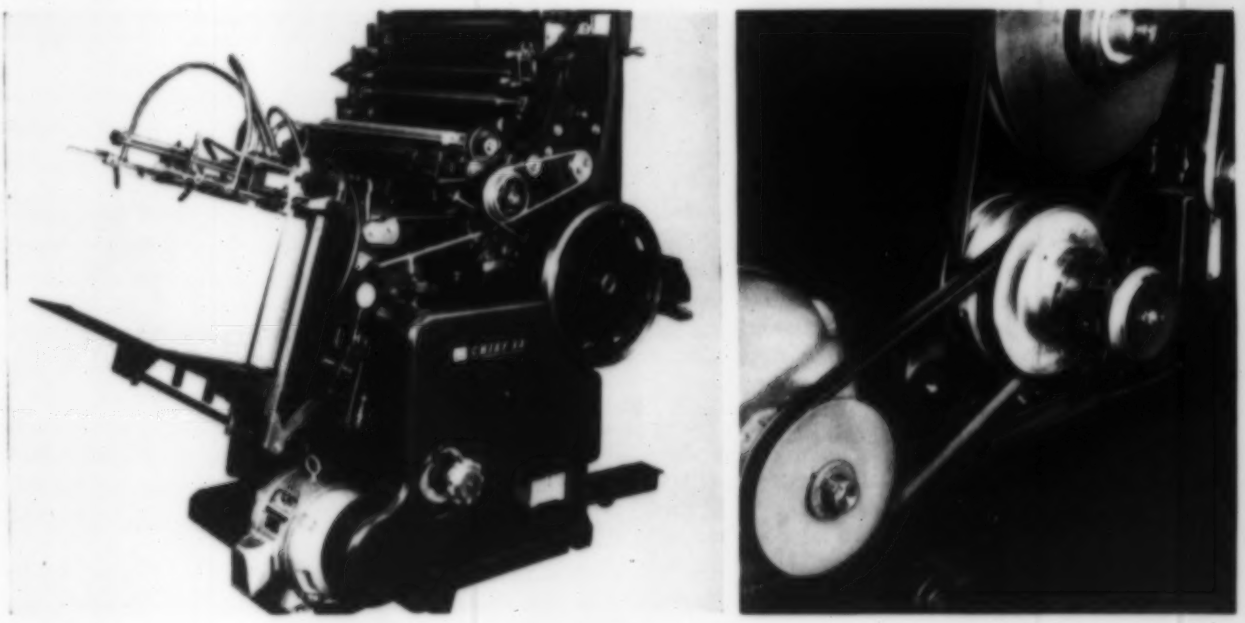


Fig. 47—Chief printing press and drive assembly which employs an adjustable compound sheave on a swinging arm to provide 3:1 speed range. Position of center sheave flange and speed are positively controlled by manual knob adjustment. Photo, courtesy American Type Founders Inc.

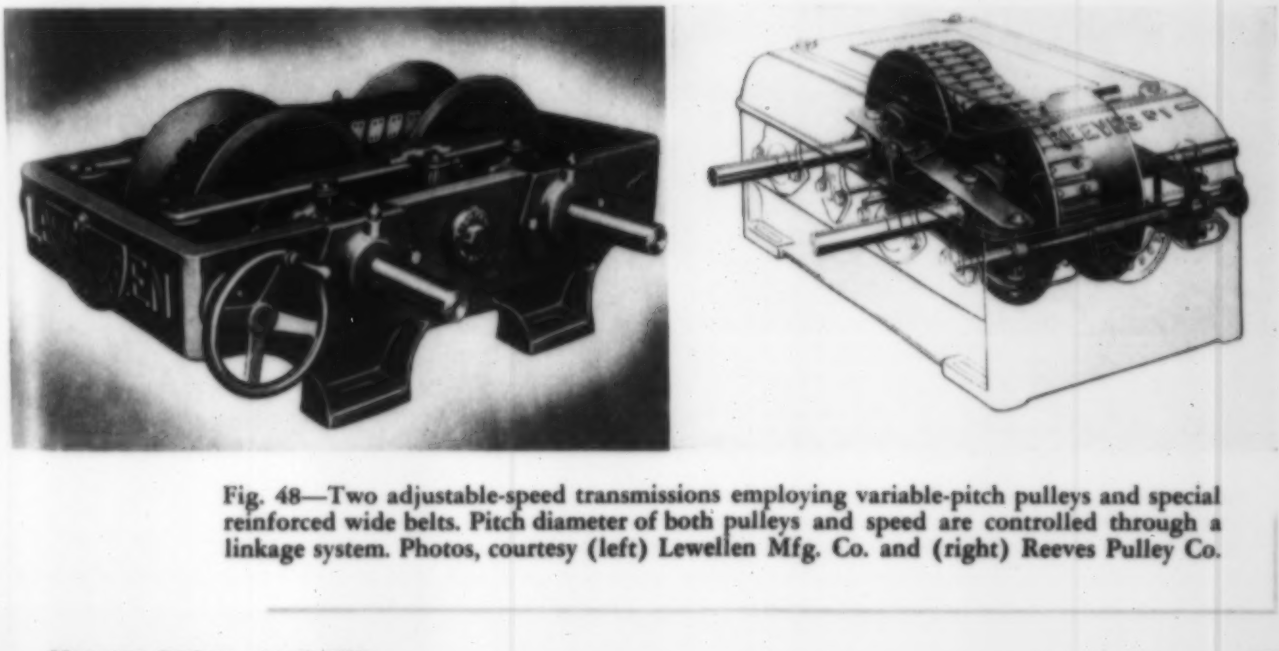


Fig. 48—Two adjustable-speed transmissions employing variable-pitch pulleys and special reinforced wide belts. Pitch diameter of both pulleys and speed are controlled through a linkage system. Photos, courtesy (left) Lewellen Mfg. Co. and (right) Reeves Pulley Co.

reliability are of vital importance. Typical functions for which these transmissions have been used include control of tension, synchronization of two or more machines or separate sections of a single machine, jogging, inching and automatic control of processing equipment where variables such as pressure, weight, or temperature may have an influence on product quality or performance.

A slightly more compact transmission is obtained with the all-metal design shown in *Fig.* 29. Power is transmitted by means of a self-forming laminated steel belt or chain which engages radial teeth on conical pulley flanges. The steel laminations or slats shuffle and reshuffle into driving contact with every meshing engagement with the pulley teeth. Principle of operation is the same as for the other variable-pitch pulley designs; as the pulley faces move in and out the pitch diameter is changed. Both pulleys are positively controlled through a linkage arrangement and operating characteristics are closely similar to the belt transmissions. Capacities vary from fractional to 25 hp and speed ratios up to 6:1 are possible in all but the maximum power units which are limited to 4:1. The entire assembly runs in oil.

The design has been well proved in industrial service and offers the advantages of all-metal construction, high efficiency and a positive form of drive. Initial costs approach those of some of the electrical systems. Properly rated and applied, however, the unit offers a highly accurate and reliable speed changer.

Despite the positive form of drive, these units are subject to the influence of varying input speed and transmitted torque values. Speed ratio changes occur under changing load conditions due to pull-in of the chain belt, but the effect is much less than that found in the other belt transmissions. Also, in contrast to the previous belt transmissions, permissible input speeds in the lower horsepower capacities run much higher, permitting direct connection with standard constant-speed electric motors. In the higher 20 and 25-hp capacities maximum input speed drops to about 500 rpm.

Fig. 49—Swift flash welder with belt transmission of type shown in *Fig.* 48 mounted integrally to provide handwheel adjustment of drive speed. Photo, courtesy Reeves Pulley Co.

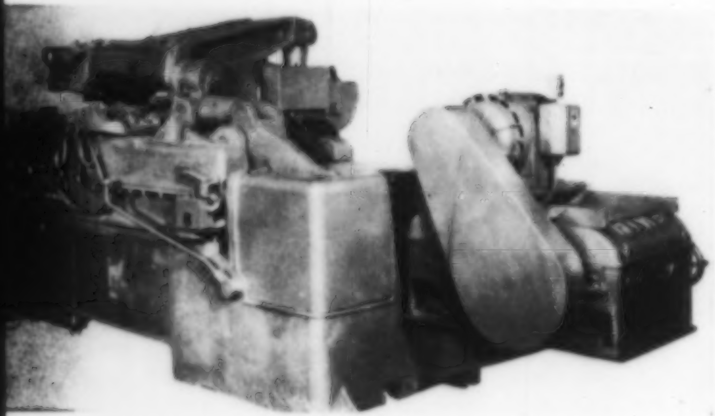
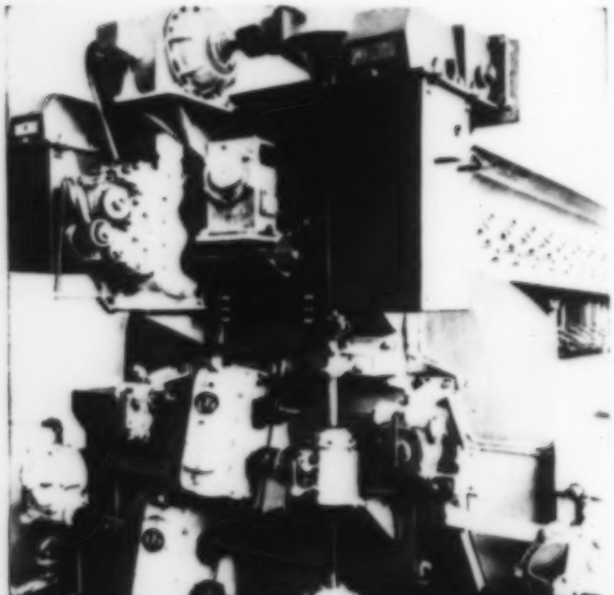


Fig. 50—Rayon pot spinning machine which uses transmissions of all-metal type shown in *Fig.* 29. Speeds of viscose metering pumps and godet wheels are controlled by three separate transmission units to regulate the amount of stretch and denier of rayon thread. Photo, courtesy Link-Belt Co.



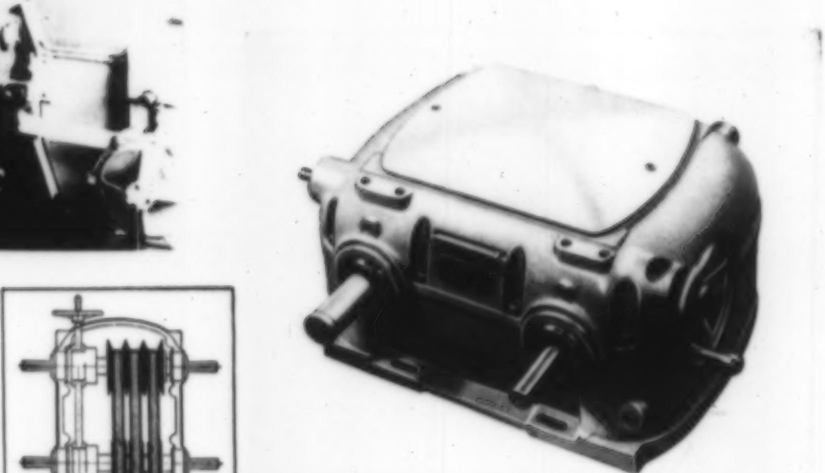


Fig. 51—V-belt transmission with linkage-operated multigroove variable-pitch sheaves for speed adjustment. Photo, courtesy Allis-Chalmers Mfg. Co.

Where a complete power package is desired, units are available in the lower horsepower capacities with integral motors.

Range of application and control possibilities parallel those of the previous belt transmissions. Typical applications vary from assembly lines to textile machines, *Fig.* 50. Various mounting arrangements and control systems, both manual and automatic, are possible. For low-speed or high-torque applications or where input speed must be stepped up, units with built-in reduction or step-up gears are also available.

Variable-pitch multiple-groove sheaves and V-belts of special construction are utilized in the transmission design shown in *Fig.* 51. Both sheaves are positively controlled through a system of worm gearing to provide speed adjustment. Belt tension is maintained by means of a weighted idler on the bottom belts, requiring orientation of the input and output shafts for different directions of rotation. For reversing service, a special stabilizer device is used to accommodate changing load conditions.

Capacities range from $1\frac{1}{2}$ to 70 hp and speed ratios to 3.84:1. Recommended input shaft speeds vary in steps of 100 from 1500 to 200 rpm, decreasing with increased capacity. Some form of auxiliary reduction drive may be required in the higher capacities. Only one style of enclosed unit is available; however, vertical mounting is possible with the tension stabilizer attachment installed. For extremely dusty conditions, a special housing must be used.

Motors and transmissions must be carefully matched to avoid exceeding load capacities under full load or starting conditions. Speed adjustment can be accomplished manually or by means of an electric pilot motor control, permitting adaptation to automatic operation. Rate of speed variation may also be regulated to suit load requirements. Units are suitable for both constant-torque or constant-horsepower applications; however, selection of transmission size will be influenced by motor characteristics and speed as well as load requirements. In operation, speeds vary equally above and below input speed.

A highly compact transmission arrangement for wide speed variation has been achieved through use of a modified form of the compound floating-sheave principle, *Fig.* 52. In this design, four variable-pitch sheaves in series are connected by two V-belts. The pitch diameters of the bottom input and output sheaves are varied by shifting the inner flanges. In the two top sheaves, the outer

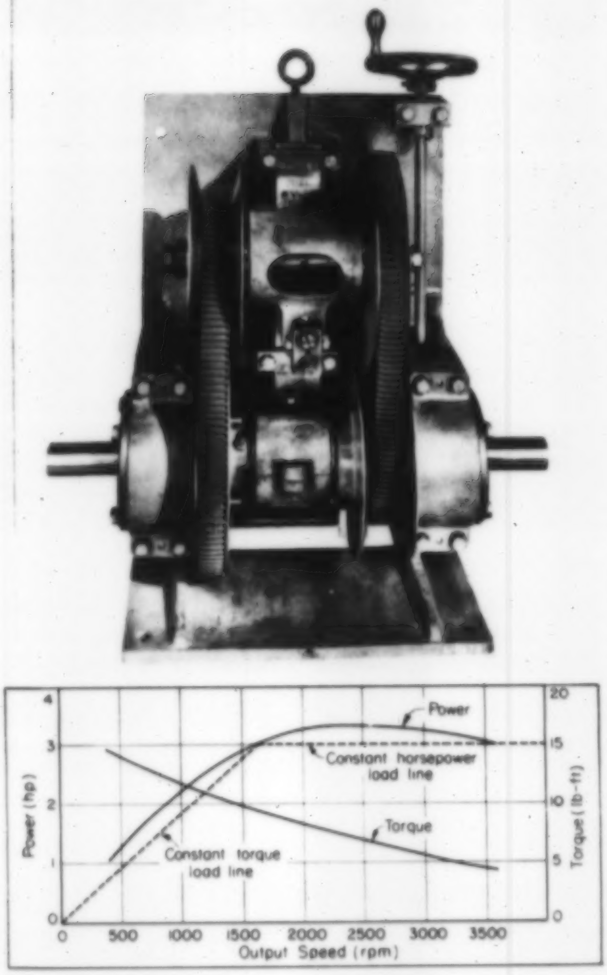


Fig. 52—Wide-range V-belt transmission based on compound sheave principle and performance curves of a typical unit with 1725-rpm input speed. Adjustment of input sheave automatically controls pitch diameter of other sheaves and output speed. Photo and drawing, courtesy Worthington Corp.

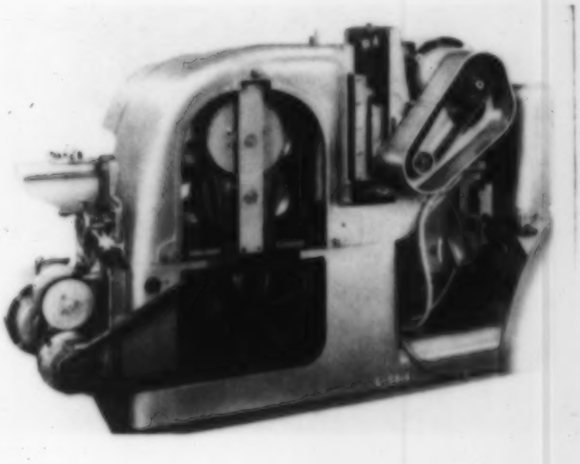


Fig. 53—Ekstrom-Carlson wood molder using transmission of type shown in *Fig.* 52 to provide infinite variation of speed of knives from 25 to 225 fpm. Photo, courtesy Worthington Corp.

Fig. 54—Three types of packaged adjustable-speed drives which employ a V-belt transmission and motor integrally mounted. Speed is controlled by means of variable-pitch sheaves on input and output shafts. Photos, courtesy (left) Reeves Pulley Co., (center) Sterling Electric Motors Inc. and (right) U. S. Electrical Motors Inc.

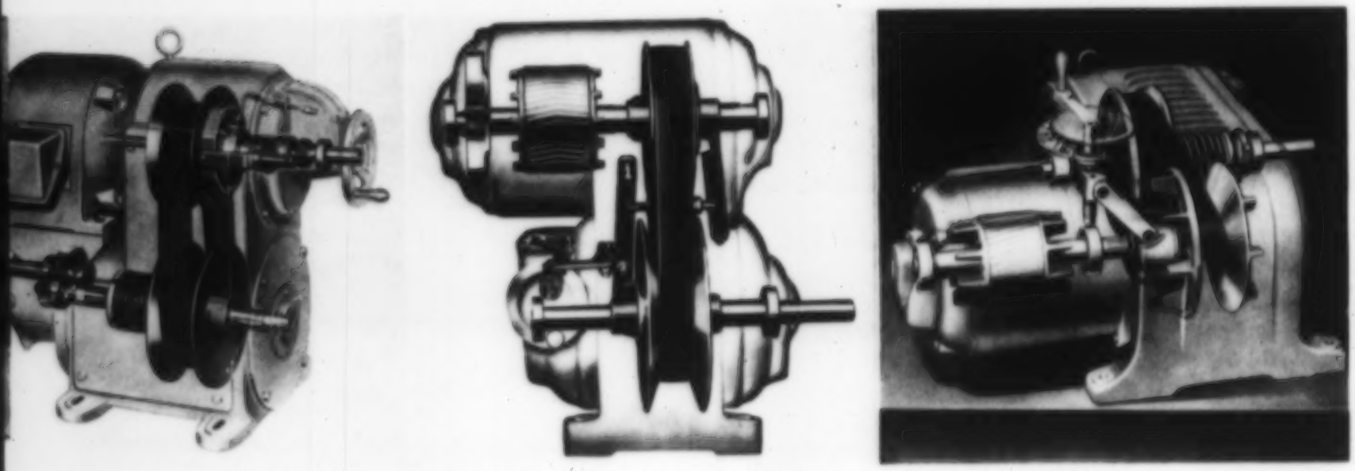


Fig. 55—Size comparison of packaged adjustable-speed drive and standard electric motor of equal power ratings. Photo, courtesy Sterling Electric Motors Inc.

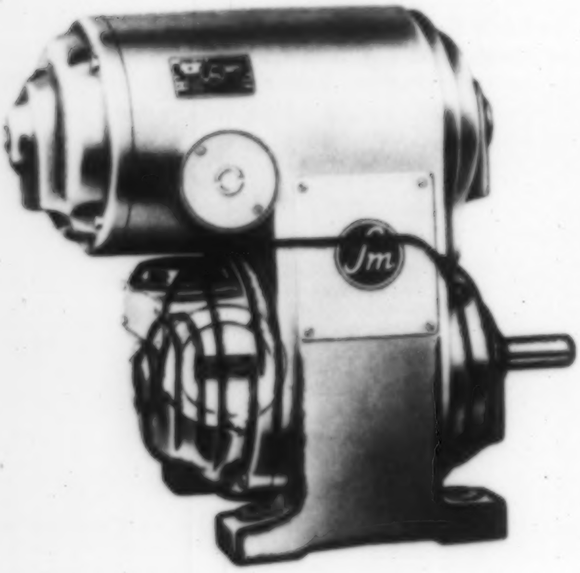
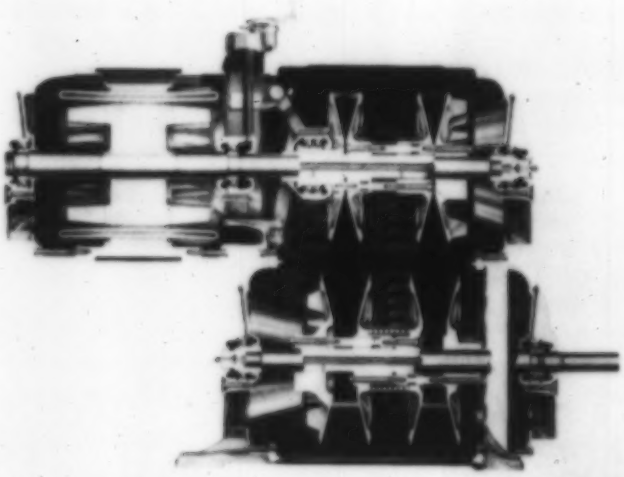


Fig. 56—Construction of typical packaged adjustable-speed drive of V-belt type for capacities over 30 hp. Photo, courtesy U. S. Electrical Motors Inc.



flanges, which are rigidly connected, move. Speed adjustment is accomplished by changing the position of the movable flange on the bottom input sheave. This action is transmitted by belt pressure, automatically adjusting the upper sheaves and the bottom output sheave to correspond. Correct belt tension is maintained by a cam device, and belt alignment is assured by the compensating flange arrangement. Sheave and belt sizes are kept to a minimum by the design, which provides speed ratios to 16:1. The space saving features of the transmission have been utilized to advantage in built-in applications, *Figs*. 4 and 53.

Capacities from fractional to 20 hp are available. Speed ratios are subject to horsepower limitations and drop to 8:1 in the maximum capacity units. All units are rated for constant torque where output speed is less than input speed and for constant horsepower when output speed exceeds input speed. Typical performance curves are shown in *Fig*. 52. This method of rating is due to the droop in the horsepower curve at high speeds, a normal characteristic of belt drives.

A wide variety of mounting arrangements are possible and both horizontal and vertical types are available. Operation in either direction of rotation or in any position is possible. Units can be obtained with an integral motor and with or without an enclosure.

In contrast to the other transmission types, input and output shafts are in line, a feature which may or may not be advantageous depending on space limitations. In addition, maintenance is facilitated by the sheave arrangement which permits belt removal and replacement without complete disassembly of the transmission. Drive may be direct, using standard motors with speeds to 1725 rpm, or through belt, gear or chain. In the latter case, overhung loads should be checked to see that bearing capacities are not exceeded.

These units generally require more attention than the other transmission types although first costs may run less. Starting in the low-speed position is recommended; otherwise belt wear may be increased. Operation at one speed setting without occasional shifting may cause the movable flanges to freeze due to lack of lubrication. Best performance is obtained at high input speeds; otherwise horsepower capacities will be accordingly reduced.

Manual lever or handwheel controls are standard; however, the units can be readily adapted to a variety of mechanical, electrical or other control systems for both remote or automatic operation. Performance characteristics of these units make them particularly suitable for a wide range of general purpose applications where speed changes are frequent and over a wide range, *Fig.* 4.

Belt Drives: A high degree of flexibility in application and control is offered by three "power package" designs which combine a motor and variable-pitch sheave transmission as an integral unit, *Fig.* 54. Construction details vary with the manufacturer but all employ dual variable-pitch sheaves mounted on parallel shafts and special ribbed V-belts to provide a compact adjustable-speed drive assembly, *Fig.* 55. Two of the designs utilize spring-loaded sheaves for control of belt tension while the other employs a positive linkage arrangement. Although more compact packaged drive assemblies have been achieved with other mechanical principles of speed adjustment, these designs usually provide the lowest initial cost primarily due to the economies of V-belt power transmission.

Capacities range from fractional to 60 hp, with maximum speed ratios of 10.7:1 in the fractional-hp sizes, decreasing to 6:1 at 30 hp and to 3:1 in the largest sizes. Double-belt drives are employed for capacities over 30 hp, *Fig.* 56. Available motor types, mounting arrangements, control systems, integral gear units and other construction features are virtually endless in variety to meet all types of environmental, space and operator convenience requirements. Depending on capacity, speeds ranging from a maximum of 10,000 rpm to a minimum of 0.6-rpm are possible although most of the "standard" units are within the 2 to 5000-rpm range. Where gear reduction is necessary, overhung load ratings of the low-speed shaft must be taken into account.

Ratings are generally on a constant-torque basis; however, performance characteristics can be readily adapted to a wide variety of load require-

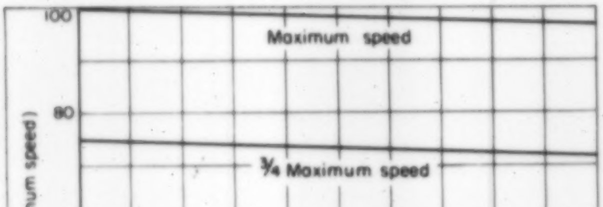


Fig. 57—Typical speed regulation curves for packaged drives of type shown in *Fig.* 54. Drawing, courtesy U. S. Electrical Motors Inc.

Fig. 58—Frauenthal grinder with electric remote-control system for packaged adjustable-speed drive in base of work table. Photo, courtesy Reeves Pulley Co.

ments. In the case of constant-horsepower applications, for example, the capacity of the transmission must be sufficient to handle full motor ratings at all speed settings and load conditions. Horsepower at low speed is the determining consideration and an oversize transmission is usually required to provide satisfactory performance. Thus, if 5 hp is needed to meet peak loads at all speed settings in a machine tool operating over a 4:1 speed range and under moderate duty conditions, it may be necessary to specify a unit with a 15-hp transmission and a 5-hp motor to carry the load. In this case, both type of service and load requirements have an influence on the transmission size. Admittedly, such modifications draw economic penalties but are necessary to assure satisfactory operating life of the transmission parts.

Whenever operating conditions deviate from normal, it is important that service factors be applied properly to avoid excessive drive costs or unsatisfactory performance. As a general rule, only the transmission size must be adjusted to accommodate the load irregularities. Motor size is determined by the *actual* horsepower requirement and the smallest frame size that will carry the load should be specified, even though a larger transmission may be needed to transfer the power. Increasing the motor size to correspond to the transmission capacity defeats the purpose of the service factor and places a greater load on the transmission.

Speed regulation curves for a typical drive unit are shown in *Fig.* 57. These curves reflect the combined performance of the motor and transmission and are indicative of the high quality of performance possible when these units are properly rated and applied. Typical applications are shown in *Figs.* 6, 58 and 59.

Initial cost of these drives may run higher than for other mechanical adjustable-speed systems of equal capacity and range but may be justified where unusual application or control requirements, accuracy of speed control, and reliability are significant considerations.

All-Metal Traction Systems: Another practical method of obtaining stepless speed adjustment is through the use of metal surfaces in frictional contact. This principle has been applied to a number of transmission designs of both the limited and infinite-range types. Only the limited-range units will be considered here. Later it will be shown how this principle has been applied to achieve output speeds down to zero rpm.

Early attempts to use metallic traction in adjustable-speed drives left much to be desired. Power transmission was usually accomplished through some form of wheel and disk arrangement, and the wheel was moved in or out from the center of the disk to provide speed adjustment. Contact surfaces were dry and frequently broke down in service.

Present transmission designs are a far cry from these early attempts and are being used successfully in a growing variety of machine applications. Properly applied, these units are efficient and reliable and offer a high degree of speed control. Metal contact surfaces are hard and highly finished, with the result that parts can be made small and the transmissions compact. Since metal parts, mostly of alloy steel, can run in oil, the speed-changing mechanism can be self-contained and splash-lubricated. Special or low viscosity oils are

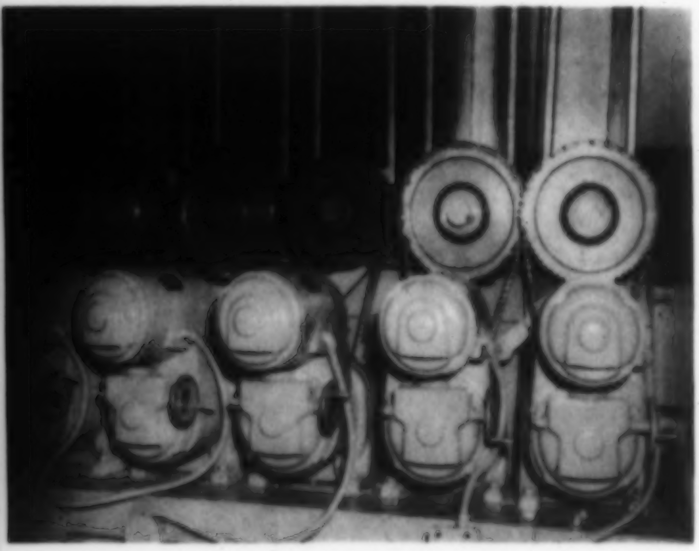


Fig. 59—Multistation extruding machine employing five individual adjustable-speed power packages to synchronize material-feed and machine-operating speeds. Photo, courtesy Sterling Electric Motors Inc.

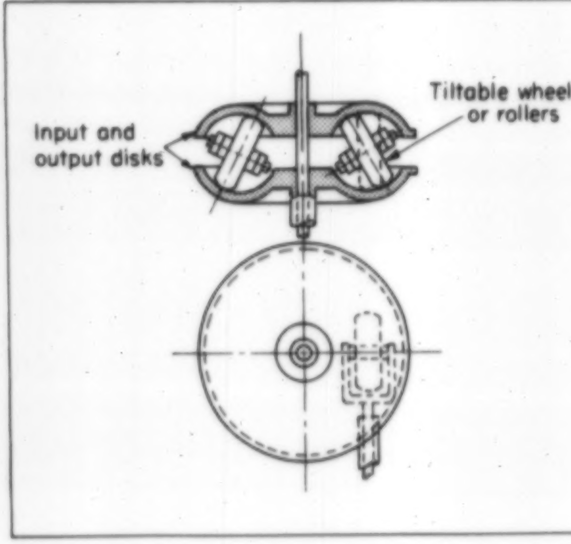


Fig. 60—Simple wheel and disk speed changer using metallic-traction principles for power transmission. Suitable for low-power applications, design controls speed by tilting wheels at different angles

used and are selected for traction rather than lubricity, although adequate lubricity must be provided. All of the designs are easily adjustable and provide stepless speed variation over their range. From an economic standpoint, they are competitive with other mechanical units of equal power and range. Present commercial types are limited to 10 hp; however, special designs have been developed in capacities up to about 50 hp.

The primary problem encountered with these designs has been the handling of sudden load changes or overloads. Ideally, construction must be such that a complete skid of the contacting parts is impossible in the event of overload. Otherwise, under the contact pressures used, instant destruction or wear of the surfaces will occur. Another important consideration is that operating temperatures be kept down, preferably below about 50 C above ambient, or contact surface life will be reduced. Cleanliness of the lubricant must be safeguarded for best performance.

In the application of these designs, it is important that continued operation for long periods at a fixed ratio be avoided, or localized wear will result. Efficiency varies with the design but values approaching 90 per cent have been obtained at speed ratios encountered in most general purpose applications.

An adaptation of the early wheel and disk principle that is being used to advantage for low-power drives is shown in *Fig.* 60. Power is transmitted between the two torus-shaped disks by means of tiltable metal rollers. In the miniature transmission shown in *Fig.* 61, two rollers or wheels are mounted in gimbals and speed adjustment is accomplished by rotating the gimbals to change both roller positions simultaneously. Contact pressure is controlled by a cam device which supplies force in proportion to the torque transmitted. These contact forces are transmitted to support bearings.

Maximum capacity is 0.025-hp and an overall stepless speed variation of 25:1 is possible with 5:1 ratios above and below input speed. Maximum speed of either shaft is 10,000 rpm in either direc-

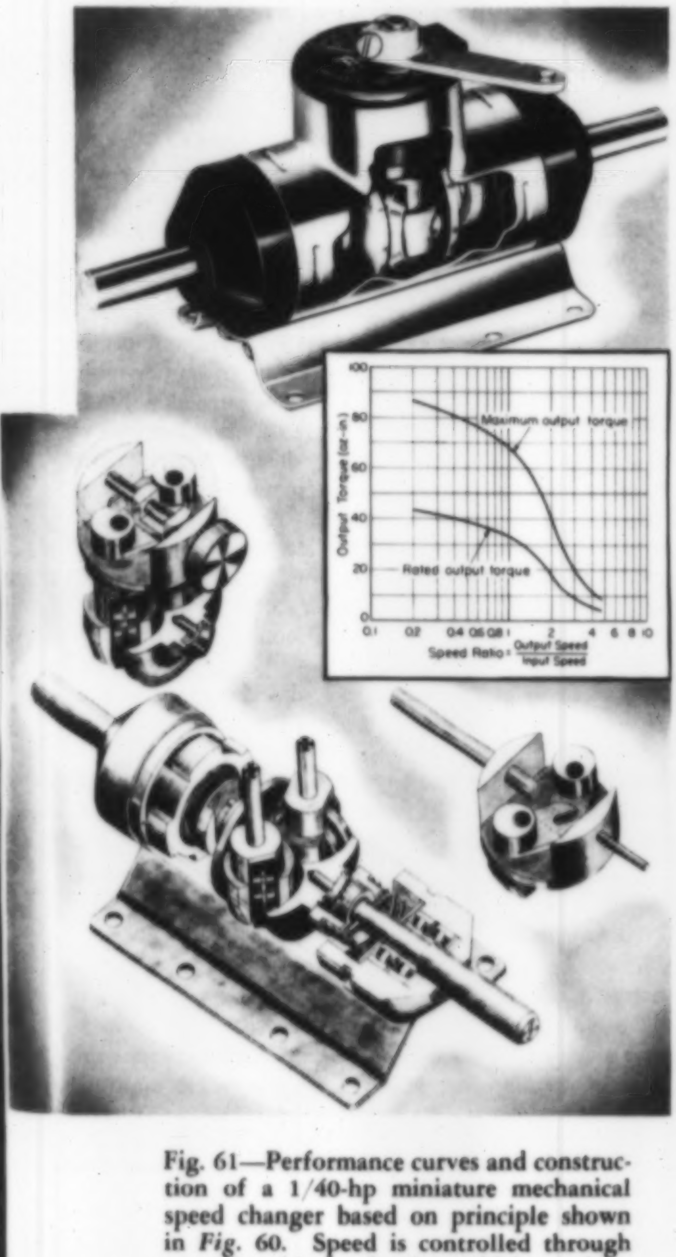


Fig. 61—Performance curves and construction of a 1/40-hp miniature mechanical speed changer based on principle shown in *Fig.* 60. Speed is controlled through an adjustable mechanism which synchronizes the rotation of two gimbals carrying the wheels and varies contact forces according to torque load. Photos and drawing, courtesy Metron Instrument Co.

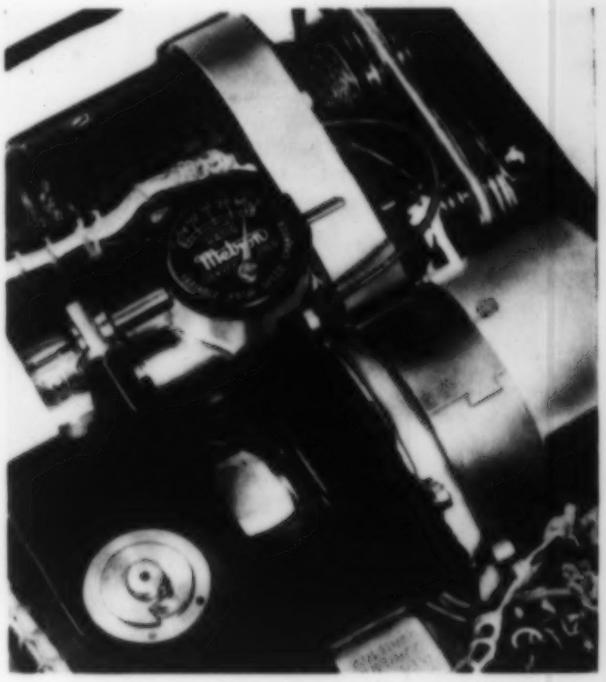


Fig. 62—Aircraft instrument drive containing built-in miniature speed changer with push-rod control. Photo, courtesy Metron Instrument Co.

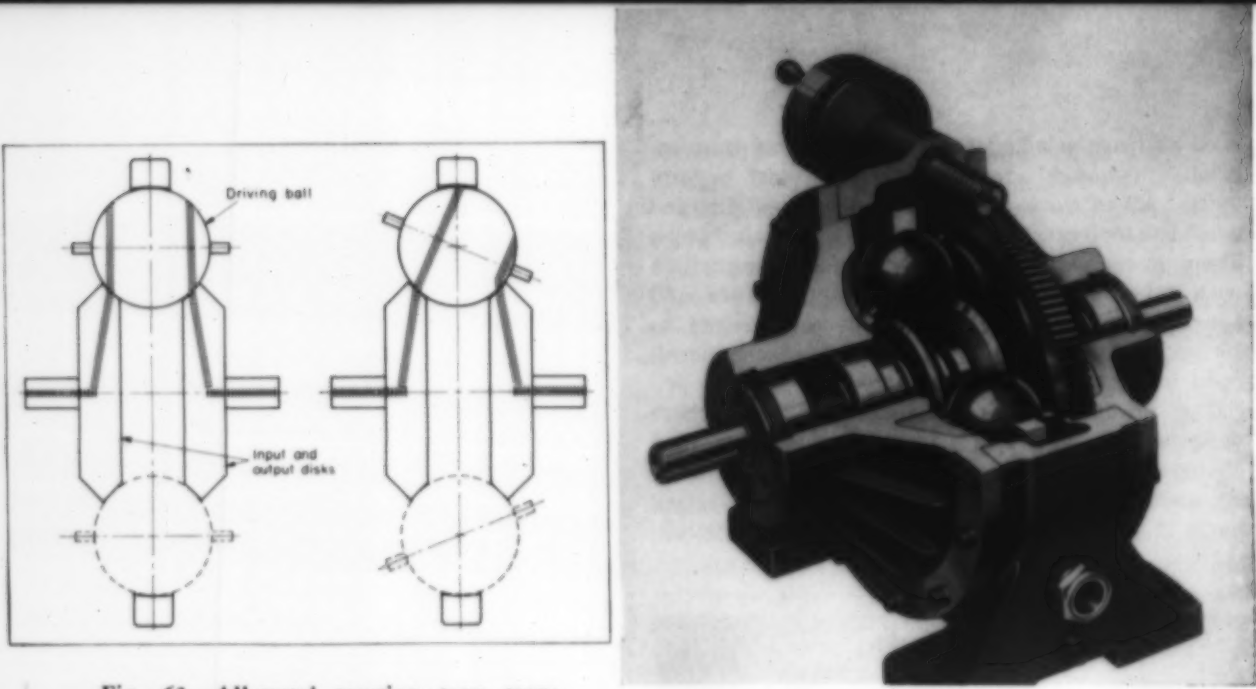


Fig. 63—All-metal traction type transmission which uses tiltable metal balls to control speed ratio between two disks on input and output shafts. Worm and gear mechanism permits adjustment of ball axes and speed. Photo and drawing, courtesy Cleveland Worm and Gear Co.

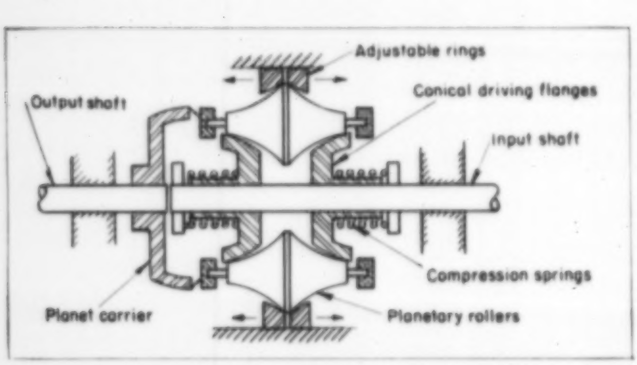


Fig. 64—Schematic view of operating elements in patented commercial adjustable-speed transmission of planetary metallic-traction type

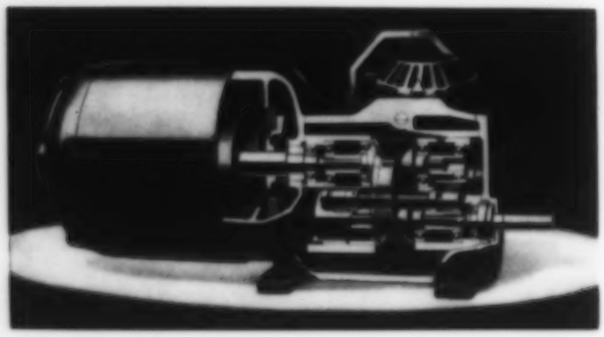


Fig. 65 — Packaged adjustable-speed drive based on metal-traction principles. Operation is similar to double variable-pitch sheave arrangement with a steel ring replacing conventional V-belt. Photo, courtesy Master Electric Co.

tion of rotation. Typical performance curves are shown in *Fig*. 61.

In this design, input and output shafts rotate in opposite directions. The units weigh only 6 oz and applications have been limited to instrument drives, *Fig*. 62, or similar uses where low power and/or compactness are needed. Efficiency of these units when operated at rated torque is 70 per cent and corresponding slip is about 9 per cent.

The same operating principle in modified form has been applied to another design which uses steel balls instead of rollers to achieve considerably higher capacities, *Fig*. 63. Speed adjustment is accomplished by tilting the axes of the balls by means of slotted plates driven by a worm and gear mechanism. Radial ball forces are balanced by a free running ring, and contact loading is varied according to the torque transmitted by a torque-responsive mechanism acting between the driveshafts and disks. Here again, the support bearings are subject to the contact forces.

Rated input capacities are dependent on input speed, varying from fractional to 10 hp at 1750 rpm. Maximum input capacity of a 10-hp unit at 1150 rpm is 7½ hp. Total speed variation obtained is 9:1, and output speeds range from ⅓ to 3 times the input speed. Rate of speed change follows a pattern closely approximating a geometrical progression.

Operating efficiencies range from 75 to 90 per cent according to load conditions. Full horsepower capacity is supplied at all speed settings, making these units particularly suitable for constant-horsepower loads. Under such conditions, however, the units are sensitive to sudden load changes and speed variations up to four per cent may result. For constant-torque applications, this drift is negligible at capacities below maximum. Speed adjustment may be obtained manually or by means of a positioning motor or linkage, permitting adaptation to a variety of remote or automatic-control systems.

The principle of planetary action which is the basis of some of the gear systems described earlier has also been applied in modified form to transmissions of the all-metal traction type, *Fig*. 64. Instead of a sun gear, two conical flanges are used. These flanges are mounted to the input shaft and are forced together by springs. Planetary rollers of mating conoid shape engage the flanges and drive the output shaft through the planet carrier. The conventional ring gear is replaced by two rings which are held stationary and engage the outer surfaces of the planetary rollers. Speed adjustment is accomplished by controlling the spread between the outer rings through a handwheel and linkage arrangement. This action in turn forces the inner cone flanges to move back and forth, thus changing the operating pitch diameters. Speed ratios of 5:1 are obtained and capacities range from fractional to 6 hp. Considerable reduction is achieved with this design. For an input speed of 1800 rpm, output speeds varying from 200 to 1000 rpm are typical. This planetary action principle has also been utilized to advantage in another transmission of the infinite-range type which will be discussed in greater detail later.

A compact "package" drive design using a metallic traction transmission is shown in *Fig*. 65. For all practical purposes, this transmission is an all-metal version of the double variable-pitch sheave arrangement discussed previously and uses a steel ring instead of a V-belt. Speed adjustment is accomplished by moving one of the cones in each "sheave." The movable cones are on opposite sides of the ring to maintain alignment and movement of both is positively controlled by a pinion and rack assembly connected to a handwheel through a worm and gear mechanism. Contact loading is provided by ring deformation under load, resulting in a wedging action. However, contact force build-up is compensated by load deflection in the anti-friction bearings supporting the two sides of the cone sheaves.

A typical application is shown in *Fig*. 66. Capacities range from fractional to 5 hp with standard speed ratios to 8:1. Some of the smaller sizes are available with ratios as high as 15:1. Many of the considerations discussed previously in conjunction with the package belt drives apply equally to these units. Flexibility in application and control is offered by a wide variety of possible motor and gear combinations, mounting arrangements and control systems, *Fig*. 7. Maximum and minimum output speeds range from 2 to 6700 rpm.

Three experimental transmission designs have also been developed and offer promise. Two are of the limited-range type and the other is capable of infinite range.

The design shown in *Fig*. 67 offers speed ratios up to 10 or 12:1 and the range, for a given input speed, can readily be positioned by selection of the output spur gearing. Power transmission is accomplished through traction rings engaging two spool elements on separate shafts. The drive ratio is determined by the position of the rings which are carried in a cage. Speed adjustment is obtained by tilting the ring support cage. This action causes the rings to "walk" to the desired position without introducing a sliding or scuffing action. The basic elements of the design are simple and rugged, of-

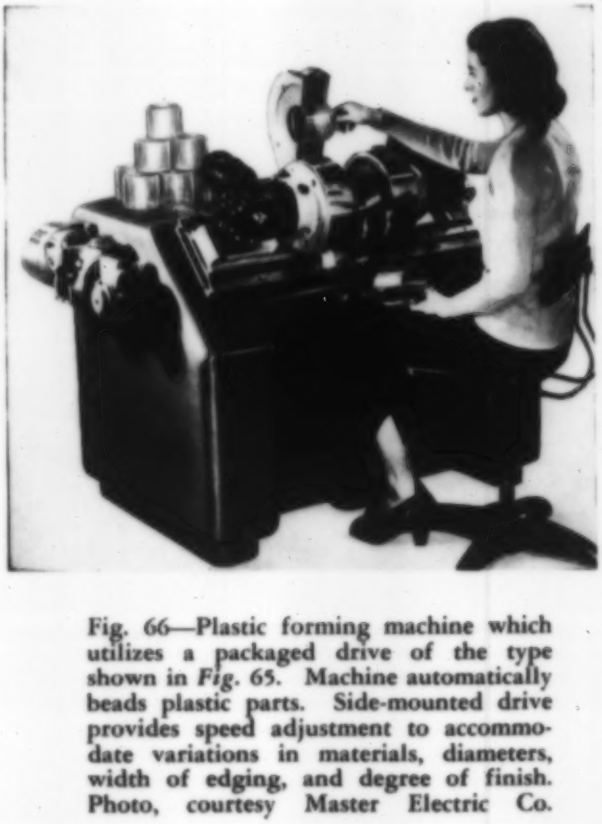


Fig. 66—Plastic forming machine which utilizes a packaged drive of the type shown in *Fig*. 65. Machine automatically beads plastic parts. Side-mounted drive provides speed adjustment to accommodate variations in materials, diameters, width of edging, and degree of finish. Photo, courtesy Master Electric Co.

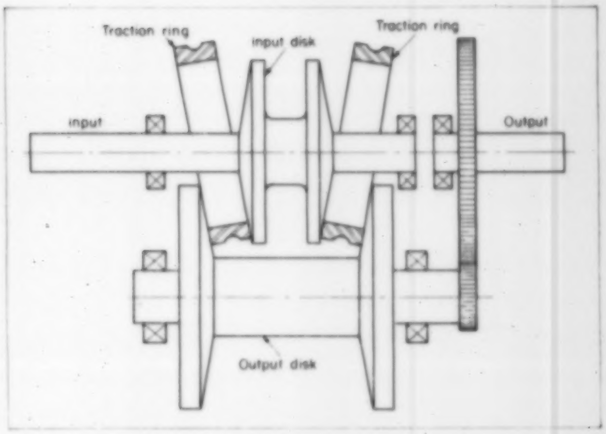
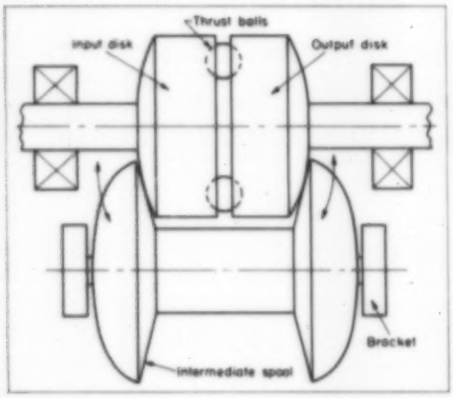


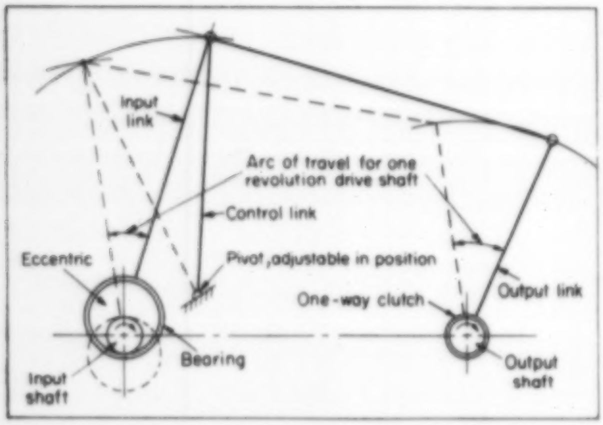
Fig. 67—Experimental dual traction-ring type mechanical speed changer. Drawing, courtesy Excelermatic Inc.

Fig. 68 — Experimental traction-spool type mechanical speed changer. Drawing, courtesy Excelermatic Inc.


Thrust balls
Input disk
Output disk
Bracket
Intermediate spool

Extra Copies

Extra copies of "Mechanical Adjustable-Speed Drives" (Parts 1 and 2) will be available in booklet form for $1.00 each when Part 2 is published in June. Advance requests may now be addressed to: Reader Service Dept., *Machine Design*, Penton Bldg., Cleveland, O.


Input link
Arc of travel for one revolution drive shaft
Control link
Eccentric
Pivot, adjustable in position
One-way clutch
Output link
Bearing
Input shaft
Output shaft

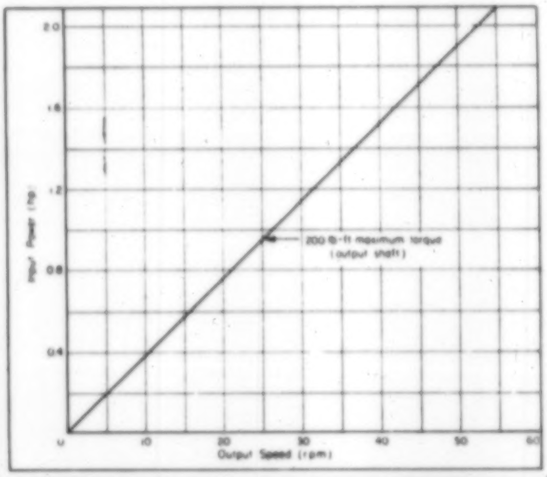
fering cost and maintenance advantages. Reaction to overload is fast and involves only a small tilt of two traction rings for compensation. Anticipated capacity range is about ¼ to 5 hp.

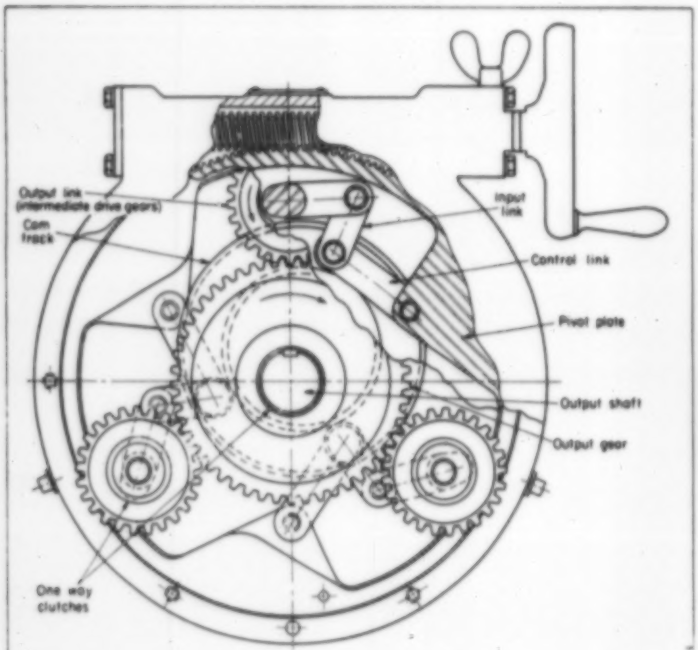
For subfractional power applications, the design shown in *Fig.* 68 offers a low-cost trouble-free speed changer with ratios varying from 5:1 in reduction to 2 or 3:1 as a speed increaser. Maximum capacity is about 1/6-hp.

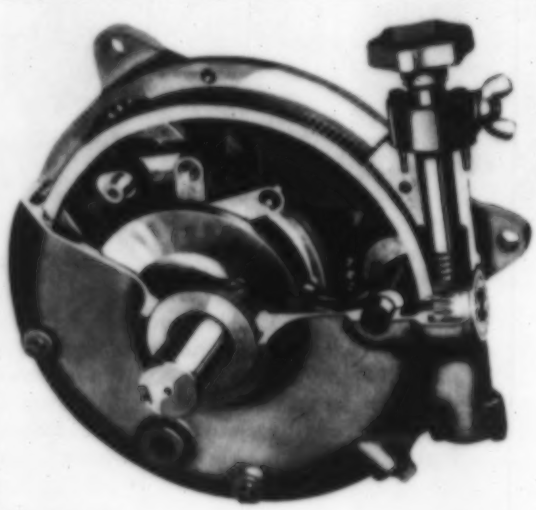
Power is transmitted from the input disk to the output disk by means of a traction spool. Engaging faces of the disks and spool have a gear tooth form. Speed adjustment is accomplished by tilting the spool, thus providing speeds below and above input speed. Spool position is controlled by means

Fig. 69—Above—Basic operating principle of variable-stroke impulse type speed changers. Output speed is adjusted by varying position of control link pivot

Fig. 70—Right and Below—Variable-stroke impulse type transmission using gears and one-way clutches for power transmission. Photo and drawings, courtesy Morse Chain Co.




Output link (intermediate drive gears)
Cam track
Input link
Control link
Pivot plate
Output shaft
Output gear
One way clutches



of a lever which actuates a U-shaped mounting bracket carrying the spool. The unit is reversible.

Variable-Stroke Impulse Transmissions: Two basic designs of the variable-stroke impulse type transmission are in use today and offer advantages in certain types of applications. One is of the limited-range type and the other has infinite range.

The basic operating principle of these designs is shown schematically in *Fig.* 69. Essentially, the operation is comparable to that of a double four-bar linkage in which the control link is the output member of one four-bar system and the input member of the other. The crank (eccentric) of the first four-bar linkage is connected to the driving shaft and the third (output) link of the second four-bar system to the driven shaft. One-way clutches are utilized to assure power transmission in only one direction of rotation. In practice, a number of such linkages are used in series to minimize the pulsating nature of the output.

Construction of a limited-range transmission of this type is shown in *Fig.* 70. Motion of the input link is regulated by a special control link mounted to a plate attached to the case and an eccentric cam track connected to the driving shaft. A roller follower at the junction of the control link and input link rides in the cam track. Thus, as the driving shaft rotates, an oscillating motion is imparted to the input link, and transmitted to the drive shaft by gears. Freewheeling clutches at each of the gears permit power transmission in one direction only. Speed is adjusted by varying the position of the control link through a worm and gear mechanism on the pivot plate.

In the design shown, three linkage and gear assemblies are employed and the "indexing" motions are overlapped so that two links are on the return stroke while the other is driving. A compact construction is achieved and ratios up to 120:1 are possible.

Application possibilities of this unit are limited to the low-speed ranges. Typical performance curves are shown in *Fig.* 70. Constant torque is supplied at output speeds ranging from approximately 1 to 55 rpm. Maximum torque output is 200 lb-ft and maximum input speed is 250 rpm. Some form of reduction drive to the input side is usually required.

Efficiency of these units, which are self contained, is about 95 per cent under full load at all speed settings. Because of the mechanical action involved the motion at the output shaft has a pulsating characteristic. However, in many of the applications for which this unit is particularly suited—feeders, mixers, materials handling equipment, etc.—this motion may be a distinct advantage. Moreover, the inertia of most driven equipment tends to smooth out irregularities, producing a uniform operating speed and reflecting the nonuniform characteristics back to the transmission for absorption by the link and clutch members.

Infinite-range designs and an overall discussion of selection and application factors for mechanical adjustable-speed systems will be presented in the next and concluding article of this two-part series.

ACKNOWLEDGMENT

MACHINE DESIGN acknowledges with appreciation the co-operation of these companies in the preparation of this article and the one to follow:

Allis-Chalmers Mfg. Co.	Milwaukee, Wis.
American Pulley Co.	Philadelphia, Pa.
American Type Founders Inc.	Elizabeth, N. J.
Chrysler Corp.	Detroit, Mich.
Cleveland Worm & Gear Co.	Cleveland, O.
Detroit Transmission Div., General Motors Corp.	Detroit, Mich.
Dodge Mfg. Corp.	Mishawaka, Ind.
Equipment Engineering Co.	Minneapolis, Minn.
Euclid Div., General Motors Corp.	Cleveland, O.
Excelermatic Inc.	Rochester, N. Y.
Falk Corp.	Milwaukee, Wis.
Fort Worth Steel & Machinery Co.	Fort Worth, Texas
Gates Rubber Co.	Denver, Colo.
General Industries Co.	Elyria, O.
Gerbing Mfg. Corp.	Northbrook, Ill.
Graham Transmissions Inc.	Menomonee Falls, Wis.
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New Standard Div., U. S. Expansion Bolt Co.	York, Pa.
Ramsey Winch Mfg. Co.	Tulsa, Okla.
Reeves Pulley Co.	Columbus, Ind.
Revco Inc.	Minneapolis, Minn.
Snow-Nabstedt Gear Corp.	Hamden, Conn.
Speed Control Div., Fairchild Engine and Airplane Corp.	St. Augustine, Fla.
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Standard Transmission Equipment Co.	Pasadena, Calif.
Sterling Electric Motors Inc.	Los Angeles, Calif.
Toledo Timer Co.	Toledo, O.
Turner Uni-Drive Co.	Kansas City, Mo.
U. S. Electrical Motors Inc.	Los Angeles, Calif.
T. B. Wood's Sons Co.	Chambersburg, Pa.
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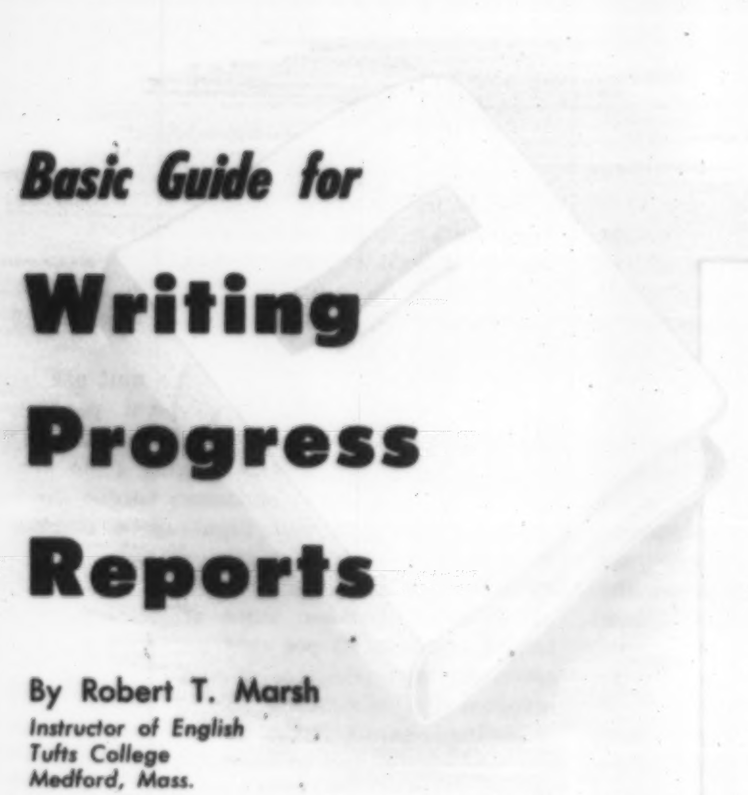

Basic Guide for Writing Progress Reports

By Robert T. Marsh
Instructor of English
Tufts College
Medford, Mass.

Table 1—Typical Progress Report Outline

1. **Cover Page.** This may include the title of the job, contract designation, authorization, engineer's name, company name, and list of enclosures.
2. **Table of Contents.** This is keyed by page reference to both the context of the report and the appendix.
3. **Foreword or Introduction.** This sets the tone for the whole report and is a transitional element between monthly reports.
4. **Discussion Section.** This is the main body of the report.
5. **Projected Program Section.** This gives an approximate view of work contemplated for the next reporting period.
6. **Appendix.** This contains blueprints, drawings, charts, etc.
7. **Abstract.** This is a precis or summary of the entire report. It is not a conclusion, but it reveals in a few words the main ideas of the whole report. An abstract is usually one typed page or less in length.

INERTIA has set in. The first of the month has arrived, and the progress report is only a set of rough notes on a scratch pad. What an ordeal is ahead for the next day, the day set aside for report writing!

Is there a *typical* report writing situation in engineering? Probably not. Perhaps the research of the month has been carefully recorded and analyzed from day to day. Perhaps the firm's goal is a report that weighs two pounds. The report may be written by a project engineer in its entirety, or he may turn over rough notes to a technical writer. But certain fundamental rules govern all report writing—and these can be particularly helpful if reports must be written frequently and cover similar information. Here is a format and bit of advice to the writer of this modern, standardized report.

A progress report, a short monthly or bimonthly account of an engineer's activities is usually written for purposes of record and of reporting to superiors. Each company modifies the general concept to fit its needs. One format which is fairly typical, and which might be used as an outline, is shown in *Table* 1.

The engineer writing the report should remember that he is establishing his reputation as well as that of his firm. He is selling technical "know-how" of an engineer or a group of engineers. So he should follow several rules:

Don't be negative. Excuses for work not done and statements of doubt may lead the reader of the report to lose faith in the company. If a statement that might be misinterpreted is made, it may put the company in an unfavorable light and might jeopardize the work of many others.

Emphasize accomplishments. Remember that the important item in a report is what was accomplished, not what wasn't done. Certainly major delays or difficulties should be mentioned, but routine problems should be minimized. "Highlight" or "point-up" accomplishments. Put important items first in the report if the chronological development allows. Too often capable engineers hide accomplishments in the back pages of a report.

Omit or subordinate the obvious. Leave out details of logistics or planning that are routine. Weed irrelevant material from the appendix, and do not clutter the appendix with drawings or work sheets not keyed to the context of the report.

Maintain continuity. Many reports are a follow-up of a previous report. Make sure that the report has transitional continuity between this month and last month's work. Any work planned in a previous report should be accounted for in a current report.

Clarify objectives. Explain the object of all experimentation and research. Do not expect the reader to be a mind-reader.

After writing, the job is not yet done. Check what has been written before handing the report to the typist. Do not expect the ordinary clerk-typist to be a genius at interpreting scrawly penmanship. Take a little care in penning a first draft.

There is no cure-all for report writing, and it seems to be here to stay. If inertia has a grip on your writing arm, the best way to shake it off is just to get down to work and start writing! Ideas on paper are easier to organize than ideas that never see the light of day.

Precision Gearing

Part 4—Control and Calculation of Inaccuracy

By G. W. Michalec*

Associate Section Head, General Precision Laboratory Inc.
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NATURE, cause and sources of inaccuracy of gear trains were reviewed in Part 3 of this series. In this concluding article, the procedures for calculating maximum and probable inaccuracy errors will be analyzed. These methods will be illustrated with a numerical example. Methods for controlling and reducing this error will also be discussed.

Accuracy calculations have considerable practical utility. After recognizing, defining, and establishing the relative importance of the various sources of gear inaccuracy, one must next analyze how these errors combine or integrate to give a total or net error for an entire gear system. Perhaps the most important benefits of calculated inaccuracies are the advantages derived for manufacture. Only those parameters critical to function would be specified closely, and in all cases tolerance would be as liberal as could be tolerated.

Maximum and probable inaccuracy errors for a given gear train design can be obtained by analyzing all of the previously listed sources of inaccuracy. This requires availability of complete manufacturing specifications and an understanding of the techniques and problems encountered in manufacture, plus a realization of the interrelation of the various parameters. Assuming this information is obtainable, there are two kinds of error figures which can be derived—maximum and probable inaccuracy.

The maximum inaccuracy error is obtained by assuming each error source to be at its maximum value, as established by the governing manufacturing tolerances. Further, since the angular orientation of the error sources has an effect, it is assumed they are all in line so as to be entirely in additive phase. This procedure is applied to each gear of a meshed pair and to each pair throughout the gear train. Thus, a maximum inaccuracy error for the gear train is obtained by summing all the component maximum errors.

The probable inaccuracy figure is obtained by using a probable value, which is usually less than the maximum, for each inaccuracy source. Also, a probable angular orientation is assumed for each gear, meshed pair and gear stage throughout the train. Therefore, the net probable inaccuracy for the gear train is the sum of all the component probable errors. Because of the nature of probability, this procedure is much more complicated and laborious than calculating maximum error.

Use of probable inaccuracy figures is much more realistic and practical than the maximum figures. This is confirmed by test results plus the mathematical realization that whenever a net error is composed of many components which can have a range of additive or subtractive values, it is highly improbable that they all will be at their maximum values and with like angular phasing. The value of a maximum inaccuracy figure is that it serves as an outside check on the probability calculations, and if there is a consistency in the ratio of maximum to probable, short-cut methods can be derived.

Technique for calculating probable inaccuracies can be developed as follows:

DISTRIBUTION CURVES AND PROBABLE VALUES should be evolved from available data. To obtain a probable inaccuracy figure for an entire gear train, it is necessary to begin with consideration of the probable value of each individual inaccuracy source. For instance, consider the total composite error (TCE). The gear drawing or contemplated design will have specified its limiting maximum permissible value, but for any particular gear its exact value is unknown. Moreover, the TCE value will vary from gear to gear. The nature of this variation depends upon a number of interrelated factors, such as machine errors, human errors, tool conditions, gear material, etc. If a quantity of gears is inspected, a distribution curve can be plotted showing the relationship between quantity and TCE. Such a curve would be peaked, perhaps resembling a Gaussian natural distribution. An assumed but likely typical curve is shown in *Fig.* 5, *Part* 1 (January 1955).

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*Also Associate, Dept. of Mechanical Engineering, Columbia University, N. Y.

Normally, most of the curve falls within the tolerance limits (otherwise manufacture would be inefficient) although the percentage and location of the peak will be affected by the factors mentioned.

With sufficient parts and inspection equipment, reliable distribution curves can be obtained for each dimension affecting inaccuracy. Then, from each distribution curve a probable value can be deduced. Unfortunately, distribution curves are not usually available, which necessitates assuming probable values for each parameter. As examples of probable values to use, *Tables* 3 through 6, *Part* 1, list in their last columns probability factors for each specified tolerance.

INTEGRATION OF BASIC ERRORS, whether found by means of distribution curves or estimated probability to give a net error for the gear, is the next step.

Previously it was mentioned that the relative angular orientation of each eccentricity error affects the net amount of eccentricity for the combination of errors. Also, the various eccentricity components are completely independent of one another, and therefore have random phasing. Thus, the theoretical distribution curve would be flat as shown in *Fig.* 6, *Part* 1. Such a flat distribution gives no clue as to a probable phasing value. A safe, conservative approach, but not mathematically rigorous, is to assume only additive phasing angles spread as a flat distribution over 180 degrees as shown in *Fig.* 7, *Part* 1. Then, the net sum of such vectors will be approximately 0.7 times the sum of their individual probable values. This net sum can be assumed to be the probable inaccuracy for the basic errors of the gear. Thus:

$$E_g = 0.7\ (E_{s1} + E_{s2} + \cdots) \qquad (6)$$

where E_g is net probable inaccuracy of gear for all error sources, and E_{s1}, E_{s2} etc., are probable error values for each inaccuracy source.

PROBABLE INACCURACY ERROR FOR A MESHED PAIR is derived from following considerations. The in-mesh angular phasing of equivalent eccentricity for net inaccuracy of each gear determines the effective operating inaccuracy of the pair. For example, if the pair has a velocity ratio of one, it can be phased in mesh so as to allow low and high points of the pitch circles to mesh, resulting in an inaccuracy for the pair equal to the sum of the net inaccuracy for each gear. On the other hand, both low points of mesh might be in phase with one another, resulting in cancellation. Also, the phasing could be any angle between these extremes, the possibilities being limited only to the number of teeth in the gear. Again, the distribution would be a flat curve similar to the distribution of *Fig.* 6, *Part* 1.

The more frequent and general case is when the velocity ratio is greater than one. Then the probable net inaccuracy of the large gear will be modulated by that of the pinion. The frequency of the modulation will depend upon the gear ratio. Component and net inaccuracy curves would resemble the backlash curves in *Fig.* 8, *Part* 1, the only difference being substitution of *inaccuracy* in place of *backlash* in the graphs and caption. Assuming equal inaccuracy errors is reasonable since paired gears are usually made to the same standards and the installation errors would be comparable for both. Also, the difference in gear radii of the meshed gears cancels out when both gear errors are plotted in terms of angular error measured at one of the gear centers.

For demonstration of this point let E_1 = Net error of gear (linear eccentricity), E_2 = Net error of pinion (linear eccentricity), R_1 = Pitch radius of gear, and R_2 = Pitch radius of pinion.

The angular error for each gear as measured at its center will be

$$\theta_1 = \frac{E_1}{R_1} \text{ and } \theta_2 = \frac{E_2}{R_2}$$

In mesh the total error of the pair, as measured on the gear center, would be the vector sum of θ_1 and θ_2, but the latter must be modified by the mesh velocity ratio. Thus, total maximum error, E_{max}, of meshed pair is

$$E_{max} = \theta_1 \nrightarrow \theta_2 \frac{R_2}{R_1} = \frac{E_1}{R_1} \nrightarrow \frac{E_2}{R_2}\,\frac{R_2}{R_1}$$

$$= \frac{E_1 \nrightarrow E_2}{R_1} \qquad (7)$$

If the gears of a meshed pair have equal linear errors, the two angular errors measured on the same gear center will be equal regardless of the gear ratio. Thus, the amplitudes of the component errors are equal.

As suggested by *Fig.* 8, *Part* 1, as velocity ratio increases, the angular phasing has less significance, and the peak value of the net inaccuracy of the pair approaches the arithmetic sum of the two individual gear errors. On the other hand, for velocity ratios near unity, the phasing angle of the individual net gear errors is very important, with the result that the probable value of error for the pair is considerably less than the sum of the two components.

With such a range of possibilities and a flat distribution curve for the angular phasing, a conservative probable phasing factor is wise. Thus, for velocity ratios near unity (1 to 2) only additive phase relationships are assumed which results in an average value equal to 0.7 times their sum. For velocity ratios greater than two, the probability factor for the pair can be taken as unity. Therefore, for velocity ratios 1 to 2,

$$E_m = 0.7\ (E_p + E_g) \qquad (8)$$

For velocity ratios greater than 2,

$$E_m = E_p + E_g \qquad (9)$$

where E_m = probable error of meshed pair, E_p = net probable error of pinion, and E_g = net probable error of gear.

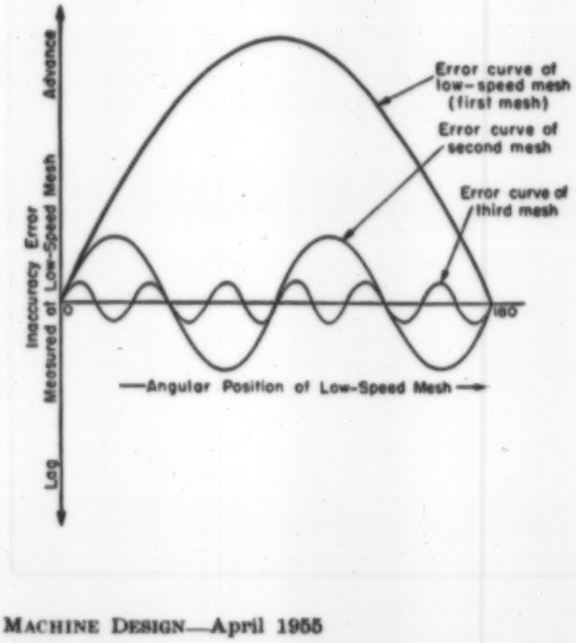
These values represent linear eccentricities. Angular values for the mesh are obtained by dividing the E_m value by the pitch radius of the gear at whose center the angular value is to be referenced.

INTEGRATION OF GEAR PAIR ERRORS THROUGH THE GEAR TRAIN is essential since each gear mesh contributes a certain error to the entire system. The total end error at some particular place in the gear train will be the vector sum of all gear mesh errors. However, the phasing of errors between meshes is a random distribution. Also, factors such as gear ratio between stages enter the picture. The greater the overall gear reduction, obviously, the less contribution of errors from succeeding meshes. To minimize the difficulties of analysis, the problem will be divided into three cases:

1. *High velocity train,* such as a gear train of at least two meshes, the first of which is a relatively high reduction (4:1 or greater). If the individual mesh errors are approximately the same magnitude, the output end of the gear train will reflect mesh errors proportional to the gear ratio. This is shown in *Fig.* 33.

The combined total error of all the meshes will depend upon the relative phasing of the meshes.

Fig. 33—Curve showing the influence of inaccuracy error of various stages of a gear train at the low-speed mesh. Only one half cycle of low-speed mesh is shown. The other half is identical, but of opposite sense



The phasing is completely random and will be hunting if the velocity ratios of the stages are not integral numbers. Again, as with the phasing of gear errors in a meshed pair, the greater the velocity ratio, the more probable the maximum peak value is the arithmetic sum of the individual mesh inaccuracies, but modified by the gear stage ratios. Thus, for high velocity gear trains, where each stage is greater than 2:1,

$$E_{TP} = \pm\left(E_{m1} + \frac{E_{m2}}{n_1} + \frac{E_{m3}}{n_2} + \cdots\right) \qquad (10)$$

where E_{TP} = total probable peak inaccuracy error of the gear train; E_{m1}, E_{m2}, E_{m3} = probable peak inaccuracy errors of first, second, and third meshes, respectively, and n_1, n_2 = gear reductions from meshes 2, 3, etc., to the first mesh.

Equation 10 reveals that for high gear reductions the bulk of the total error will be limited to the first mesh. Succeeding mesh errors will only slightly modulate the primary error curve in both magnitude and frequency.

2. *Low velocity train,* where the phasing is very important when the gear stage ratio is near unity. Phasing is random and there is an equally good chance of any degree of additive or subtractive relationship. For such a condition, the conservative approach of predominantly additive phasing is wisest. Thus, the total probable error of gear trains having gear stage ratios of from 1 to 2.5 would be

$$E_{TP} = \pm\, 0.7\left(E_{m1} + \frac{E_{m2}}{n_1} + \frac{E_{m3}}{n_2} + \cdots\right) \qquad (11)$$

where the symbol definitions are the same as for Equation 10.

3. *Unity velocity train* in which it is likely that the probable total gear train error is smaller than indicated by Equation 11. As the number of meshes increases and the errors are all equally weighted, since there is no reduction, the probability is that more error is cancelled so that the resultant net error is smaller. Therefore, for this type of train, the total inaccuracy error is obtained by taking the square root of the sum of the squares:

$$E_{TP} = \pm\sqrt{(E_{m1})^2 + \left(\frac{E_{m2}}{n_1}\right)^2 + \cdots} \qquad (12)$$

Any one of Equations 10, 11, 12 applies to a gear train if all of its stages conform to the conditions set forth for that equation. However, it is possible to have a train in which there is a combination of conditions, i.e., high speed and low speed stages. In that case, the integration of mesh errors must be done piecemeal, applying each equation to the appropriate stages.

Note that the integration of inaccuracy errors throughout a gear train varies significantly from the integration of backlash which was reviewed in *Part* 1. The net backlash of a gear train is the direct addition of the backlash for each mesh. However, inaccuracy must be a vector addition. Thus, as more stages are added to a gear train, the backlash increases proportionately, but the probable inaccuracy need not increase proportionately and may actually decrease because of vector addition.

AVERAGE PROBABLE INACCURACY is based on the concept that error varies from advancing to lagging positional relationship, as previously shown in *Part* 3.

Thus, it can be considered as a continual plus and minus variation with gear rotation, passing through zero twice per cycle. The previously derived procedures for obtaining probable inaccuracy apply to its peak value, and it will still go through positive, zero and negative values. The sense of the inaccuracy error is of no significance in most applications, and therefore, the average value is not zero, but equal to the average value of either the positive or negative loop of the inaccuracy curve. Since the inaccuracy curve is approximately sinusoidal, the average inaccuracy error will be 0.7 times the peak value. Thus the equation for the average value is:

$$E_{pe} = 0.7\, E_{TP} \qquad (13)$$

OPERATION FACTOR, or type of service, can influence inaccuracy error. Because the inaccuracy error goes through a range of values, advantage can be taken of this in certain special applications. Consider, as examples, dials, indicators and rack positioners, which may not be used throughout their entire gear range. For instance, extreme accuracy of a speed or direction dial may only be necessary in one specific operating quadrant. In that case, the gear inaccuracy will only go through part of its range. Thus, if the calibration is done at the proper place, the effective inaccuracy of the system can be reduced significantly. Therefore, depending upon the details of the specific application, there will be some operation factor applied to the probable peak inaccuracy error.

Maximum and probable inaccuracies can be obtained by use of the following procedures:

PROBABLE INACCURACY for a gear train is obtained by means of the following summarized procedures:

1. *Basic gear and installation errors:* For each gear, determine the contributing error sources, and from the applicable tolerances on gear drawings and specifications, obtain the maximum values of the errors. Modify the maximums by applying the proper probability factor such as listed in *Tables* 3 through 6, *Part* 1.

2. *Net gear error:* Multiply the sum of the various probable errors of step 1 by 0.7 to obtain the net gear error (Equation 6).

3. *Net mesh error:* Obtain the probable net error for each meshed pair by means of Equation 8 or 9 depending upon the velocity ratio.

4. *Conversion from linear to angular error:* All the previous error calculations could have been done in terms of eccentricity magnitude (linear measure) or in angular measure. If the former, this is a good point at which to convert to angular measure using Equation 3, *Part* 3, where e is the net probable total eccentricity for the mesh and R is the radius of the gear at whose center all of the inaccuracy figures are to be measured.

Note if the application is special, such as spring-loaded gears or unidirectional drive, Equation 5, *Part* 3, is to be used rather than 3.

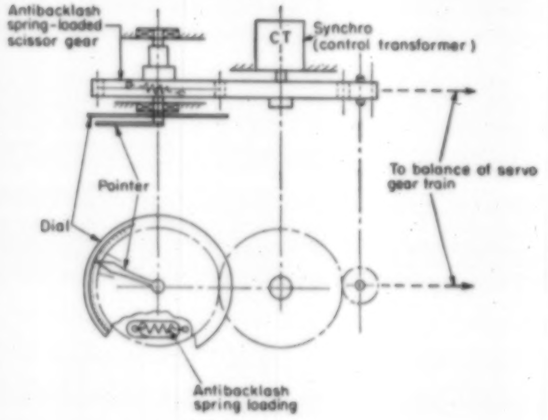
5. *Net overall train error:* Integrate the net errors for each meshed pair by means of Equation 10, 11 or 12, depending upon which is applicable. For mixed gear trains, apply the appropriate equation to the various portions of the train and integrate accordingly.

6. *Average inaccuracy:* The average inaccuracy value is obtained by multiplying the peak figure obtained in step 5 by 0.7 for an assumed approximately sinusoidal error curve.

7. *Operation factor:* If the application has an obvious operation factor both the peak and average values (steps 5 and 6) can be modified by it to obtain net operating inaccuracy figures.

MAXIMUM INACCURACY is derived by the same

Fig. 34—Simplified gearing diagram for Example 1, involving a positioning synchro and dial indicator


Antibacklash spring-loaded scissor gear
CT
Synchro (control transformer)
To balance of servo gear train
Pointer
Dial
Antibacklash spring loading

DESIGN CONDITIONS

1. **Both gears are AGMA Class Precision 1B, 48 diametral pitch, 20-degree pressure angle, 96 teeth.**
2. **The manufacturer of the synchro specifies 0.001 TIR (total indicator reading) for the shaft rotated in its component bearings.**
3. **The dial shaft is ¼-inch diameter with ⅛-inch diameter steps at the ends to fit ⅛-inch ball bearings. The runout between the ¼ and ⅛-inch diameters is 0.0005 TIR max.**
4. **Dial shaft ball bearings are ABEC Class 5, with a radial play range of 0.0003-0.0007.**
5. **The diameters and tolerances of the dial shaft, synchro shaft and gear bores are as per *Table* 5, *Part* 1, Class Precision 1.**

sequence of operations excepting no probability factors are applied, and steps 6 and 7 are omitted.

Inspection is necessary because the preceding analysis of inaccuracy prediction is based upon specified dimensions and tolerances applying to the influencing dimensions. These figures must be achieved if the calculations are to be of any significance. Any disregard of tolerances, particularly the critical ones, will result in serious disruption of existing or assumed distribution curves with the result that the probable inaccuracy figure will not be reliable. Any departures from the design specifications must be accounted for in recalculation of the probable inaccuracy.

Methods of controlling and reducing inaccuracy are largely indirect, special, relatively difficult to apply, and are only partially effective.

The first consideration is really not a method but, rather, emphasis upon effective control. All dimensions affecting inaccuracy should be well controlled, particularly the total composite error. It is the one parameter which can be conveniently inspected; therefore, the design drawing can specify a reasonable value consistent with the inaccuracy error that can be tolerated. This is an important point, for total composite error is often the largest error source and also the one most measurable and controllable.

The second means of inaccuracy control is in terms of the gear radius. That is, for a specified magnitude of total composite error, the angular value will be diminished directly and proportionately by using a larger pitch diameter. However, there is a practical limit to this, for the larger the gear, the more difficult it is to maintain the same total composite error tolerance. Thus, for each design a proper weighing of size limitation, cost and desired accuracy must be made in compromising and fixing these quantities.

A third point worth considering, similar to the previous one, is to locate the gear meshes of high velocity ratio near the critical portion of the train. This will have the effect of demagnifying the contributions of meshes on the high-speed end of the train.

Table 9—Inaccuracy Sources and Magnitudes for Example 1

Error Component	Maximum Error (TIR)*	Probability Factor	Probable Error (TIR)
Dial Gear:			
Total composite error ..	0.001	2/3	0.0007
Bore-shaft clearance ..	0.0008	2/3	0.0005
Shaft runout between gear mounting and bearing diameter	0.0005	1	0.0005
Bearing inner race runout	0.0002	1	0.0002
Total	0.0025		0.0019
Synchro Gear:			
Total composite error ..	0.001	2/3	0.0007
Bore-shaft clearance ...	0.0008	2/3	0.0005
Component shaft runout	0.001	0.7	0.0007
Total	0.0028		0.0019

* Total indicator reading.

A fourth consideration is to attempt to eliminate some of the error sources. The eccentricity due to the clearance between the gear bore and shaft can be essentially eliminated by making the assembly a press fit, or where reasonably possible, the gears and shaft could be integral, thus eliminating shaft error (bow, shoulder runout, etc.) as well as clearance. In some cases where extreme precision is warranted the shaft is assembled to the gear blank and the teeth are cut from the shaft bearing mounting diameters. Also, the error due to radial play of ball bearings can be eliminated by axial preloading of the bearings. Additional errors of ball bearing shaft and housing fits could be eliminated by designing for fits ranging from line-to-line to light press.

Another way to diminish inaccuracy, although cumbersome and costly, is to phase the various eccentricity sources so as to obtain maximum cancellation. This is done during the assembly of the gear train by a trial and error procedure of rotating the gear relative to its shaft and the shaft relative to the inner race of its ball bearing and also interchanging parts until the desired tolerable value of inaccuracy is achieved. This method is difficult and expensive in that the errors are small and, therefore, the adjustments fine and critical requiring considerable time of a skilled assemblyman. For these reasons, this method is not recommended but has been mentioned to indicate the kind of special efforts that can be made to diminish inaccuracy.

A variation of the preceding method, which also has limited use, is the special case of 1:1 meshes. To minimize the inaccuracy, during inspection the gears are segregated according to the magnitude of total composite error, and the location of the low and high points of each gear are marked. Then, at assembly, if the high and low points are meshed, the errors will tend to cancel one another. For best cancellation, the error in each gear should be equal and the total composite error should be predominantly runout component. Again, because this method requires special inspection and assembly, plus being limited to a 1:1 velocity ratio, it is limited in application.

Numerical examples of inaccuracy calculations are presented here to develop further the understanding and significance of the preceding analysis. They are based upon utilization of tolerances and probability factors listed in *Tables* 3 through 6, *Part* 1.

EXAMPLE 1: Assume it is necessary to determine the maximum and probable inaccuracies of the gear mesh shown schematically in *Fig.* 34. The synchro remotely positions a direction dial which can be read to 3 minutes of arc by means of a vernier. The velocity ratio between the synchro and dial is 1:1 and to eliminate backlash the mesh is spring-loaded by means of an anti-backlash gear.

Since the gear ratio is unity the gear sizes are equal and there is no significance as to which shaft is used for referencing the error, although from function, it should be the dial since it is positioned by the synchro.

The solution is subdivided into the same steps as the text of the analysis.

a. Basic gear errors: The first step is to list all the inaccuracy sources and their magnitudes, both maximum and probable. For the probable values the suggested probability factors in *Tables* 3 through 6 will be used. Note that due to the spring-loading, the bearing radial play has no significance. For convenience, this information is listed in *Table* 9.

b. Net gear errors: The next step is to integrate the errors to obtain a net error for each gear. The maximum error is the sum of each maximum source and has been totaled in *Table* 9. The probable maximum will be taken to be 0.7 times the sum of each probable component, Equation 6. Thus:

For dial gear, maximum error is 0.0025 TIR and probable error is 0.7(0.0019) = 0.0013 TIR.

For synchro gear, maximum error = 0.0028 TIR and probable error = 0.7(0.0019) = 0.0013 TIR.

Notice the above error values are listed as TIR (total indicator reading) values since that was their designation in the tabular listing in *Table* 9. Conversion to eccentricity values will be made in a later step.

c. Total mesh error: Having calculated net errors for each gear, the total mesh errors must be obtained next. The maximum mesh error is the sum of the two maximum gear errors, but the probable mesh error is the sum of each probable error modified by the factor 0.7 as per Equation 8 since the velocity ratio is unity. Thus:

At dial shaft, maximum mesh error is 0.0025 + 0.0028 = 0.0053 TIR and probable is 0.7(0.0013 + 0.0013) = 0.0018 TIR.

d. Final error in angular measure: The foregoing figures were carried through as linear errors in terms of TIR (total indicator readings). This was done as a matter of convenience since the pertinent data from design specifications come in this form. However, the final answer is to be in angular measure. To obtain this figure the TIR value must be converted to an eccentricity value by taking one half of it; then the eccentricity figure is converted to angular inaccuracy error by means of Equation 5, *Part* 3. Note Equation 5 is used rather than 3 because this is a spring-loaded mesh. Thus:

Net inaccuracy error for mesh is $\frac{1}{2}$ $(0.0053/R)$ + $\frac{1}{2}$ $(0.0053/R)$ tan 20°, maximum peak, where $R = 1.00$ and tan 20° = 0.364. Therefore, maximum peak error is 0.0036 radians = 12.4 minutes and probable peak error is $\frac{1}{2}$ (0.0018) + $\frac{1}{2}$ (0.0018) 0.364 = 0.00123 radians = 4.2 minutes.

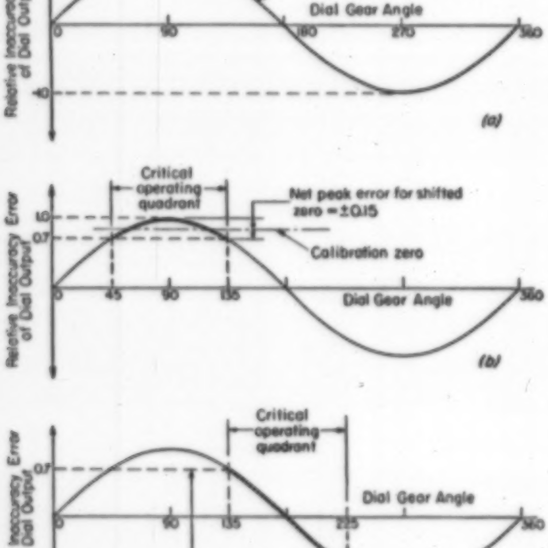
Note that the probable error is approximately 1/3 the maximum. Thus, if only a maximum inaccuracy error had been calculated it would have resulted in a much more pessimistic picture. This could conceivably result in rejection of the design, despite its being suitable in most cases.

e. Operation Factor: No information was given with the problem to indicate special operating conditions. However, to illustrate practical possibilities, assume the dial is to be used for high accuracy over a range of only one quadrant. Then the probable peak error could be scaled down to either 0.15 or 0.7 of its full value given above. This is obtained as follows:

If the critical operating portion of the dial is only one quadrant, then only 90 degrees of the approximately sinusoidal inaccuracy error curve would be traversed. For any given 90-degree length, it can be assumed that the error will be zeroed at its mid point. Then the peak error will depend upon which 90-degree portion of the sine curve is used.

To illustrate, assume *Fig.* 35*a* to be a sinusoidal inaccuracy error curve having a maximum probable peak error corresponding to the value calculated above. Then the possible extreme cases

Fig. 35—Inaccuracy curve of dial gear, Example 1, illustrating, *a*, inaccuracy error for full 360-degree rotation of dial, *b*, maximum reduction of peak error, when 90-degree operating quadrant is centered about top (or bottom) peak of the basic sine curve and, *c*, minimum reduction of peak error, when operating quadrant is centered about axis of sine curve



of reduced peak error are shown is *Figs.* 35*b* and 35*c*.

In the first figure, the quadrant of operation is assumed to be centered about the peak value of the sine curve. Then the total range of error in the critical quadrant would be from 0.7 to 1.0 times the peak value of the sine curve. Thus, if the dial is calibrated and zeroed at the average value of these two errors, the peak error in the quadrant would be reduced to ± 0.15 of the original peak value of the sine curve. Of course shifting the zero calibration in this manner means that in some positions outside the critical quadrant the error will be greater than originally. This reduced peak error represents the most favorable case, resulting in maximum reduction of peak error. The least reduction of peak error would occur for the case shown in *Fig.* 35*c*. Here the operating quadrant is centered about the axis of the sinusoidal error curve. Then the peak errors will be ± 0.7 of the original peak value.

In practical application it is usually too difficult to demand centering of the critical quadrant in the most favorable orientation. Therefore, it would be in order to assume the probable value is nearer the higher figure 0.7.

Note this analysis of operation factor was for one specific case of 90 degrees of operation. For other ranges of operation the reduction of peak value will be different. Each case must be analyzed separately. The case just presented is meant to be an illustrative guide.

EXAMPLE 2: To illustrate combinations of gear stages, the following problem is presented:

For the schematic gear train shown in *Fig.* 36, it is required to determine the maximum and probable inaccuracy errors from the synchro shaft to the counter shaft.

a. Basic errors and mesh errors: By the same procedures used in Example 1 the maximum and probable inaccuracy errors for each mesh can be calculated utilizing the probability factors in the tables. The details of this will be omitted, since the previous example will suffice; instead, detail analysis will begin with these errors. However,

Table 10—Mesh Errors for Example 2

Mesh	Shaft for which error is measured	Inaccuracy Errors (Minutes) Maximum	Inaccuracy Errors (Minutes) Probable
M-1	S-1	± 7.2	± 4.1
M-2	S-2	±10.6	± 5.6
M-3	S-3	±13.2	± 7
M-4	S-4	±58	±21

DESIGN CONDITIONS

1. All gearing 20-degree pressure angle, 48 pitch, number of teeth, ratio and AGMA class as noted on schematic.
2. All shaft-gear bore dimensions as per *Table 5, Part* 1.
3. Synchro and counter shaft runouts 0.001 TIR.
4. Jack shafts S-2, S-3 and S-4 are centerless ground stock with a maximum runout of 0.0005 TIR between the gear mounting diameter and the shaft bearing diameters.
5. Jack shafts S-2 and S-3 bearings are ball bearing ABEC Class 5 with a total radial play of 0.0003 to 0.0007. Jack shaft S-4 has ABEC Class 1 ball bearings.

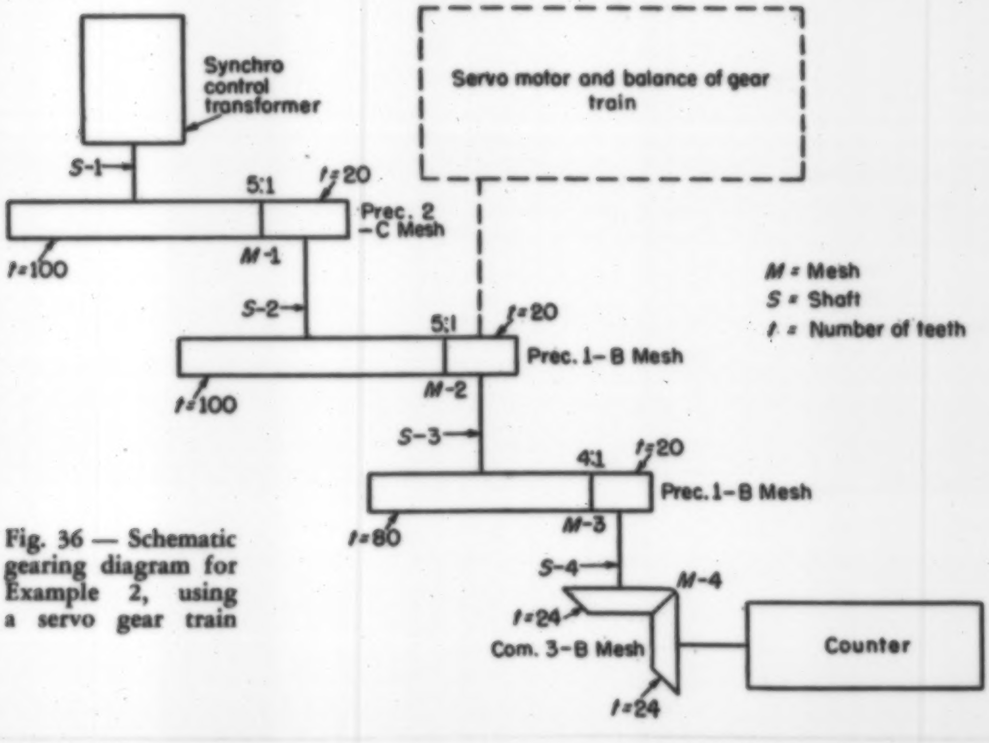


Fig. 36 — Schematic gearing diagram for Example 2, using a servo gear train

sufficient design information has been given for the reader to verify these figures. Notice, though, for this application Equation 3 is used rather than 5 since this gear train is without antibacklash gears, and the drive is bidirectional. Also, mesh errors are obtained by means of Equation 9 for meshes 1, 2 and 3 because the velocity ratio is appreciable. However, for mesh 4 Equation 8 is used. Thus, *Table* 10 is evolved for mesh errors.

b. Total gear train errors: Having obtained the mesh errors these must be properly integrated to give the total gear train error measured at the synchro shaft. From the schematic it can be seen that each mesh has substantial velocity ratio. Therefore, Equation 10 is the proper means for calculating the probable train error.

$$E_{TP} = \pm \left(E_{m1} + \frac{E_{m2}}{n_1} + \frac{E_{m3}}{n_2} + \frac{E_{m4}}{n_3} \right)$$

substituting:

$$E_{TP} = \pm \left(4.1 + \frac{5.6}{5} + \frac{7}{25} + \frac{21}{100} \right)$$
$$= \pm\ 5.7 \text{ minutes}$$

The maximum inaccuracy is obtained by addition of the maximum mesh values modified by the appropriate velocity ratio.

Thus:

$$E_{max} = \pm \left(7.2 + \frac{10.6}{5} + \frac{13.2}{25} + \frac{58}{100} \right)$$
$$= \pm\ 10.4 \text{ minutes}$$

These sample calculations reveal that complete inaccuracy analysis is detailed and lengthy. However, this can be partially offset by neglecting error sources which are relatively small, such as ball bearing errors, and shaft runout. Also, high-speed meshes contribute little error, because of the reduction when measured at the low-speed end of the train, and therefore can be omitted. In Example 2 the error contributions of meshes 3 and 4 could have been neglected with merely a 10 per cent loss which, considering the nature of the analysis, is tolerable in most cases.

Furthermore, if a series of calculations were to be made, and the gears and other significant parts conform to a fixed design standard, it is possible to calculate standard mesh errors and use these values for each gear train calculation.

From a series of calculations, it is possible to derive a ratio of probable to maximum errors which is fairly consistent. However, to rely upon this ratio, in order to omit probable calculations, is possible only if the governing conditions are identical or nearly so. This is because the ratio is related to the tolerance magnitude in that the smaller the tolerances, the less spread between the probable and maximum values.

This article concludes a series on the general subject of precision gearing and its inherent faults in regard to function. Information on these subjects is lacking in both gearing text books and technical publications. Therefore, the intent of this series has been to contribute toward the bridging of this gap in knowledge.

The sections dealing with the determination of probable errors are admittedly a pioneering effort. The methods outlined are not rigorously mathematical, but they do represent a determination toward establishment of reliable procedures for their calculation. To date, probable backlash and inaccuracy calculations have yielded reliable results as substantiated by actual test data. However, it is anticipated that reliability will increase as more test data and actual distribution curves become available.

EXTRA COPIES

Copies of the entire series of "Precision Gearing," bound as a complete pamphlet, may be obtained for $1.00 each from Reader Service Dept., *Machine Design*, Penton Bldg., Cleveland 13, O.

They Say . . .

"Two score years ago there were several industries held back by the engineering design methods of that time, which specified 'factors of safety' in some types of machines as high as 10 or more. Certain inventors built machines violating those rules, amongst which were aeroplanes. Had these been built according to the factors of safety required, they would never have gotten off the ground."—CROSBY FIELD, *president, Flakice Corp.*

"There is growing recognition by employers, as well as by engineering educators of the need of a more liberal education for engineers."—A. V. WILKER, *trustee, Union Carbide Education Fund.*

"When engineering graduates come into industry, industry assumes responsibility of carrying on where engineering educators have left off. While industry welcomes and seeks young engineers, it recognizes that engineering graduates are by no means finished products. Engineering educators have trained them to become engineers, and were not expected to turn out these young men as finished engineers. Today's technology is far too complex to expect of any young man that he step into a full-scale engineering job without further training by and in industry. The responsibility of understanding this further training program is one which industry gladly accepts." — JOHN J. CRONIN, *vice president in charge of manufacturing, General Motors Corp.*

Graphical Method Quickly Solves

Tank Head Volumes

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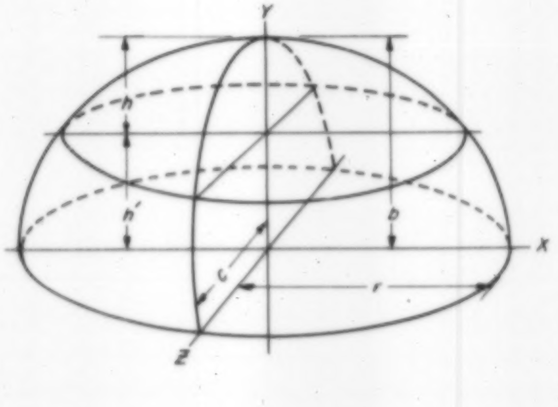
Reaction Motors Inc.
Rockaway, N. J.

CYLINDRICALLY shaped units such as accumulators, storage tanks, etc., are usually designed with hemispherical or semiellipsoidal heads, particularly in high-pressure applications. The partial and total volumes contained in heads (tank ends) of various sizes and shapes must often be calculated in original design and development work.

Formulas for calculating total and partial volumes are listed in *Table* 1. Nomenclature is illustrated in *Fig*. 1.

Fig. 1 — Dimension nomenclature of a semiellipsoidal tank end. An ellipsoidal segment is also shown

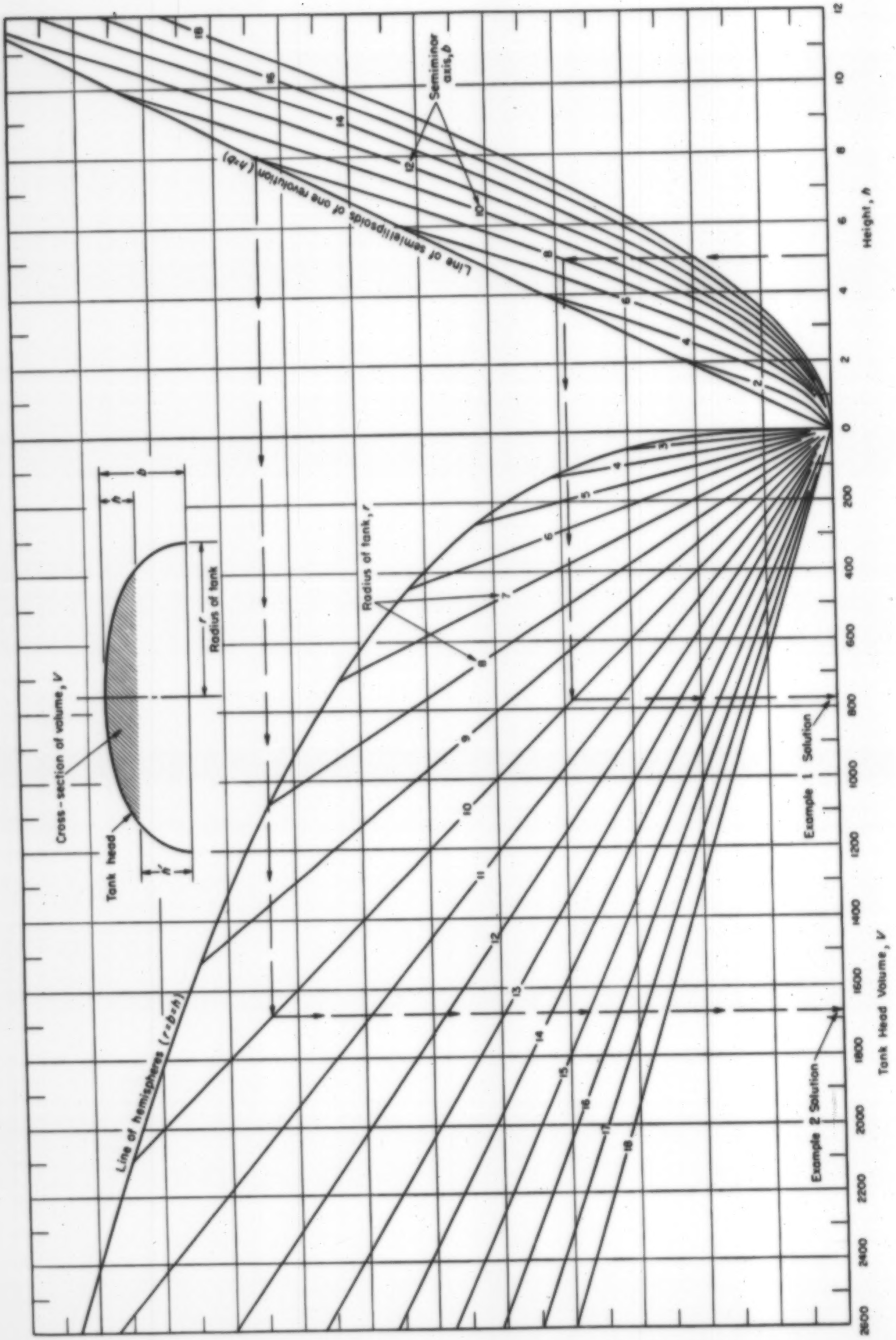


Formula Relationships: The most general volume expression listed in *Table* 1 is Equation 1. It gives the volume of an ellipsoidal segment with an elliptical base. When the ellipsoidal segment has a circular base, i.e., when $c = r$, Equation 1 becomes Equation 2. For spherical segment where $b = c = r$, Equation 1 reduces to the form shown in Equation 3. The formula for the volume of a semiellipsoid with an elliptical base is given in Equation 4 and for a circular base in Equation 5. Equation 6, the simplest form, denotes the volume of a hemisphere. Equation 1 reduces to Equation 4 when $b = h$, Equation 5 when $b = c = h$, and Equation 6 when $b = c = h = r$.

Graphical Solution: Use of the formulas in *Table* 1 for a number of calculations could become tedious. However, the chart shown in *Fig*. 2 permits quick and reasonably accurate solutions of Equations 2, 3, 5 and 6. Chart solutions for Equations 1 and 4 are not included because the cross-section of most tanks in circular, i.e., $r = c$ in *Fig*. 1. Actually the solution chart is based upon Equation 2; Equations 3, 5 and 6 are simply special cases of this expression. Any unit of length may be used so long as consistency is maintained for a given volume determination.

The following examples will show how the solution chart is used.

EXAMPLE 1: A tank head has a semiellipsoidal shape with a circular base, $r = 10$ inches and $b = 8$ inches. What is the volume of the ellipsoidal seg-


Height, h
0
2
4
6
8
10
12
Semiminor axis, b
2
4
6
8
10
12
14
16
18
Line of semiellipsoids of one revolution (r=b)
Radius of tank, r
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Line of hemispheres (r=b=h)
Cross-section of volume, V
Tank head
Radius of tank
r
b
h
h'
Example 1 Solution
Example 2 Solution
Tank Head Volume, V
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600

ment where $h = 5$ inches?

Solve by using the chart in *Fig*. 2. Starting at $h = 5$, move up vertically until the line $b = 8$ is intercepted. Then move horizontally to the left until the line $r = 10$ is reached. Drop straight down to the tank head volume scale and read $V = 775$, which is the required answer in cubic inches.

Example 2: What is the volume of the whole semiellipsoidal tank head in *Example* 1?

Referring to the *Fig*. 2 chart again, $b = h = 8$ in this case. Starting at $h = 8$ move up vertically until the line $b = 8$ is crossed. Note, however, that this intersection occurs on the "line of semiellipsoids of one revolution." Thus volume determinations of semiellipsoids with circular bases can be made by starting at the intersection of the b value and the line of semiellipsoids of one revolution. To continue, move horizontally left as before until the line $r = 10$ is intercepted. Then move vertically down to the V scale and read 1675, which is the answer in cubic inches.

Fig. 2—Opposite page—Chart for determining total and partial volumes of elliptical and hemispherical tank ends. The chart solves Equations 2, 3, 5 and 6, *Table* 1

The solution chart in *Fig*. 2 may also be employed to find volumes of spherical segments and hemispheres whose formulas are given in Equations 3 and 6, respectively. To solve Equation 3, proceed as in *Example* 1. To solve Equation 6 it is only necessary to locate the value of r on the "line of hemispheres." Dropping straight down to the volume co-ordinate determines the answer in a single step.

If it is desired to find the volume between the base of a semiellipsoid and the base of an ellipsoidal segment which are a distance h' apart, the solution must be conducted in two steps. The following example details the technique to employ for solving this type of problem.

Example 3: An elliptical tank has a circular base with $r = 10$ inches and $b = 8$ inches. What is the volume contained by the tank end between the base of the semiellipsoid and the base of an ellipsoidal segment where distance h' between these two bases is 3 inches? The two bases are parallel.

Obviously, the volume of the semiellipsoid minus the volume of the ellipsoidal segment is the desired volume. Here $h = b - h' = 5$ inches. Thus, b, h and r values for the ellipsoidal segment in this example are the same as those in *Example* 1 and the volume determined in the same manner is again 775 cubic inches. Similarly, the dimensions of this semiellipsoid are the same as those in *Example* 2, and the volume is 1675 cubic inches. Therefore, the required volume between the two bases $h' = 3$ inches apart is 1675 cubic inches minus 775 cubic inches, giving a final result of 900 cubic inches.

Table 1—Volumes of Tank Heads

Tank Head Shape	Volume	Equation No.
Ellipsoidal segment		
Elliptical base	$V = \frac{\pi r c h^2}{b^2}\left(b - \frac{h}{3}\right)$	1
Circular base	$V = \frac{\pi r^2 h^2}{b^2}\left(b - \frac{h}{3}\right)$	2
Spherical segment	$V = \pi h^2\left(r - \frac{h}{3}\right)$	3
Semiellipsoid		
Elliptical base	$V = 2/3\, \pi r b c$	4
Circular base	$V = 2/3\, \pi r^2 b$	5
Hemisphere	$V = 2/3\, \pi r^3$	6

DESIGN ABSTRACTS

Designing for maximum readability and efficiency of . . .

Indicators and Controls

By Alphonse Chapanis
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UNTIL recently, engineers had little scientific information to use in designing the most readable kind of dial. They usually made their dials meet other requirements — engineering convenience, for one thing. Round dials, for example, are probably popular because, as one engineer puts it, "You can wrap ten inches of scale around a three-inch dial." Customer preferences have also had a lot to do with the kinds of dials used. Automobile speedometers are designed primarily to "look nice."

Recently, however, there has been some research on the shapes of dials, and one of these studies is worth noting as an illustration of the kind of thing that can be done about it. In this study, five different types of dials were compared: vertical, horizontal, semicircular, open-window, and round. The percentage of incorrect readings made by 60 subjects in reading these dials was then charted. Since there was a total of 1220 readings for each dial, the differences between dials are highly significant from a statistical point of view. The open-window dial gave the fewest errors; there were only five out of the whole batch of 1020 trials. The round dial was next best with 11 per cent, and the horizontal and vertical dials were poorest.

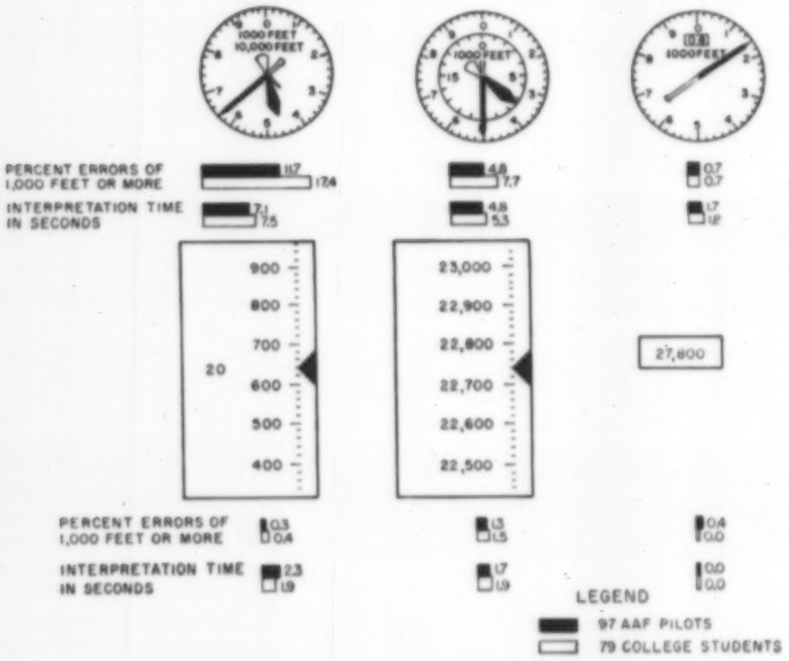

Fig. 1—A conventional three-pointer altimeter, upper left, and five other dial designs with their respective errors and interpretation times as found in experimental studies with both AAF pilots (black bar) and college students (white bar)

Multirevolution dials, such as conventional aircraft altimeters, are among the most difficult to read, probably because people must combine the readings of two or more separate pointers. They are used, nevertheless, because one revolution of a pointer on a circular dial does not give enough scale length to provide the needed accuracy. For instance, the altitude range in which conventional aircraft operate (roughly 0 to 40,000 feet) cannot possibly be covered accurately in one revolution of a pointer on a dial of ordinary size. The clock is another such instrument, as are also the aircraft tachometer and airspeed indicator. A conventional three-pointer altimeter and the five designs which gave the best results in experimental studies are shown in *Fig.* 1.

Although the shapes of dials are an important consideration in dial design, another human problem in dial reading is even more important—the way in which the scale is graduated and numbered.

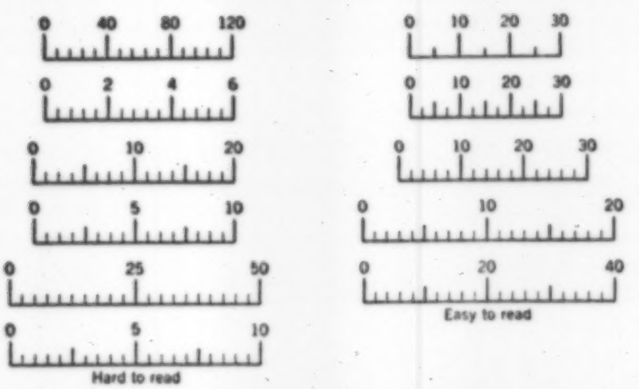

Fig. 2—Examples of scales illustrating good and poor graduation and numbering systems

On the basis of the results of studies of this problem, engineering psychologists have been able to formulate some general principles about good and bad numbering systems. Perhaps the results of these studies can best be summarized by the examples of good and bad scales shown in *Fig.* 2. In general, the relative difficulty of these scales is about the same if we multiply or divide the scale numbers by 10. This means that the top scale on the right would be easy to read whether the numbers went 0, 1, 2, 3, or 100, 200, 300. The same is true for the other scales.

Other Types of Indicators: Sometimes a dial is not needed when some other kind of quantitative indicator would be better for the purpose. Pictured in *Fig.* 3 is a schematic diagram of a radar scope. The dark line extending upward toward the upper left-hand corner is a cursor line which can be rotated about the face of the tube by the radar operator. When the cursor line intersects the target, the radar operator reads the bearing of the target from the scale around the scope face; in the drawing it reads 315 degrees.

In one large experiment performed on this kind of a radar indicator, a direct-reading counter was substituted for the scale and the two were compared. The results of a large series of trials showed that when radar operators had to read the bearings of targets from circular scales like those shown in *Fig.* 3, 10 per cent of their readings were in error by 1 degree or more. Furthermore they required, on the average, 3.3 seconds to swing the cursor around to a target and read the scale. When, however, they performed exactly the same operations with the direct-reading counter, only 2 per cent of their target bearings were in error, and on the average it took them only 1.7 seconds to read the bearing. Thus, the substitution of a direct-reading counter for the circular scale resulted in a 50 per cent saving in time and a decrease in the number of errors to one-fifth of the original number.

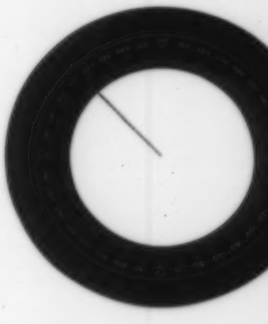

Fig. 3—This circular scale used in a radar scope required more time to read and produced more errors than a direct-reading counter

Movement and Control Problems: One of the persistent problems encountered in nostandardization of movement of controls, is controls which do not follow "natural" directions of movement. Fortunately, experimental solutions for these problems are often easy to come by. Typically, a control is left in a neutral position and

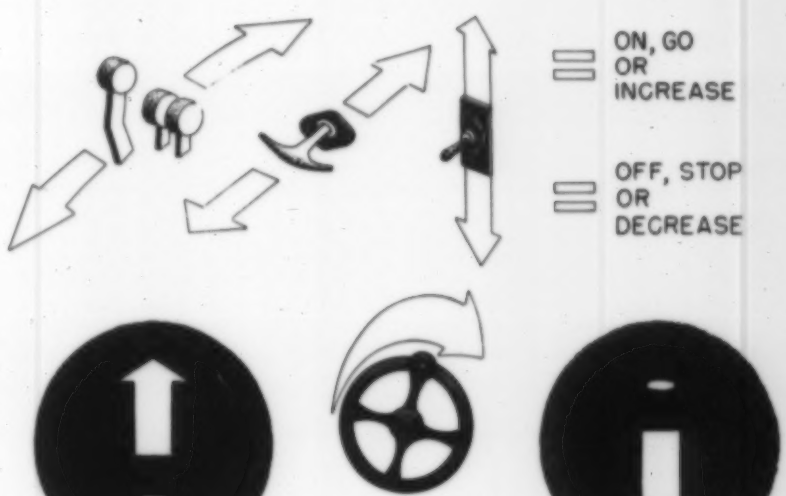

Fig. 4—Preferred directions of movement for levers, push-pull controls, toggle switches and handwheels to produce desired response

the experimental subject is told, "Make the machine go faster by operating this lever," or "Turn the machine on by flipping that switch." All the experimenter has to do is watch what the subject does first.

Some preferred directions of movement that have come out of tests on hundreds of people are illustrated in *Fig.* 4. Toggle switches should move upward for *on*, *go*, or *increase* and downward for *off*, *stop*, and *decrease*. Levers and controls which move inward and outward should also follow consistent directions of movement. In the case of handwheel controls, clockwise movements of the handwheel should move displays downward if the display is to the right of the handwheel and upward if it is to the left. Counterclockwise movements should produce the reverse.

Not all movement or control problems are as easily settled as are those regarding the direction of movement. Often there is no common-sense principle, or simple set of observations, to which the designer can turn for the solution of a control design problem. In such a case the only recourse is to experiment. The results of a typical experiment on control movement are shown in *Fig.* 5. Here the problem was concerned with the optimum gear ratio for the movement of an indicator.

Results of this experiment showed that the task could be dissected into three distinct components. The first is simple reaction time—the time it takes for a person to get going. Note that it is relatively constant for all gear ratios. The second is primary movement time, the time it takes to move the needle to about the correct vicinity. If a pointer is geared to move only a small amount for each revolution of a knob, primary movement time is long; on the other hand, it is short if the pointer movement is large for each revolution of the knob. The third factor is secondary movement time, the time required for fine corrective movements once the pointer is about the right vicinity.

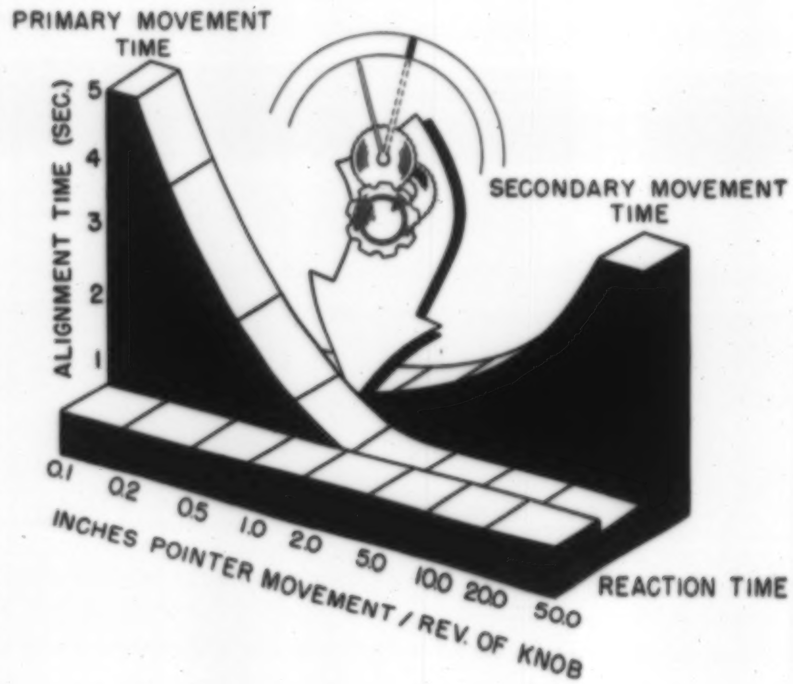

Fig. 5—Diagram of time required to move and set an indicator using various gear ratios

Secondary movement times are very nearly the inverse of primary movement times. When a single revolution of the control produces a large amount of pointer movement, it is difficult to get precise settings because the pointer moves too fast. If, on the other hand, the pointer moves only a small amount for each revolution of the knob, then it is easy to get exact settings. The best overall ratio occurs at that point where the sum of the three time components is at minimum.

From *"Some Applications of Experimental Psychology to Machine Design" in Office of Naval Research* Research Reviews, *June*, 1954.

Analyzing shock and vibration effects with

High-Speed Photography

By Robert D. Hawkins
Sperry Gyroscope Co.
Div. of The Sperry Corp.
Great Neck, N. Y.

TO SEE what is actually happening to equipment during shock and vibration, engineers have been using high-speed motion photography and have depended on other means for analytical data. However, with proper techniques high-speed motion picture films can be analyzed to provide accurate measurements of displacements, velocities and accelerations. Under these circumstances, high-speed motion photography becomes an all-purpose tool for the study of packaging tests and other shock and vibration phenomena.

High-Speed Cameras: Two commercially available high-speed motion picture cameras are the Kodak high-speed camera, manufactured by Eastman Kodak Company, and the Fastax high-speed camera, manufactured by Wollensak Optical Company.

A typical set-up for taking high-speed motion pictures is shown in *Fig.* 1. The high-speed camera shown is a 16-mm Fastax which has a maximum picture taking rate of 8000 frames per second. Special incandescent lights provide the high level of illumination necessary. Of particular interest for measurement applications of high-speed motion photography is the function of the timing-mark generator. This instrument produces a series of well-defined light and dark areas on the edge of the film at time intervals corresponding to either 100 or 1000 cycles per second. These marks serve as an accurate time reference.

Application: The type of picture which lends itself easily to the measurement process emphasizes the motions to be measured by being as close to the subject as possible and contains special markers which are easy to measure in the film-reading equipment.

Scenes from films which were taken primarily for measurement purposes are shown in *Fig.* 2. These pictures show only the white line markers which are fastened to the objects whose motion is to be measured. The size and location of the markers is determined by the nature of the motions to be measured. For instance, a vibration test like the one illustrated requires very fine line markers and a close view because the motions to be measured are so small. With large subjects, brackets sometimes have to be constructed to get markers representing the various motions into a small field of view.

Film Analysis: The procedure for analyzing film described here is one used successfully at Sperry Gyroscope Co. and found to be accurate, rapid and economical. The equipment needed are ordinary engineering tools plus some device to read the film. There are several film readers on the market now which are designed for taking measurements from 16-mm film.

The first step in analyzing a film is to view it in motion with a projector and to mark off the lengths of film in which the motions to be studied occur. This usually varies from 1 to 10 feet of film depending on the subject and the picture taking rate. As the next step, the total number of frames to be read over the interval to be studied is decided upon. Viewing the film in motion helps to determine this. Jerky, uneven motions indicate predominant high-frequency variations which require frequent readings to be shown accurately. For most packaging tests, 100 frames or readings is sufficient to measure accurately all of the important variations that exist in a given pulse or cycle of motion.

Reading the film consists of measuring the distance on the film between the stationary reference and the object or objects undergoing motion for as many frames as necessary. Measurements are usually made in the line of motion but can be made in two mutually perpendicular directions to describe motions that are not unidirectional. In the reading process, the value of the white line markers that were placed on the objects photographed becomes apparent. It is very easy to center the black hairline of the microscope or film reader on the white marker lines of the film. With good quality lines about 0.002-inch wide, an inexperienced operator can get the same reading on repeated tries to within ±0.0001-inch. In similar measurements made from contrasting edges the variations that can be expected with an inexperi-

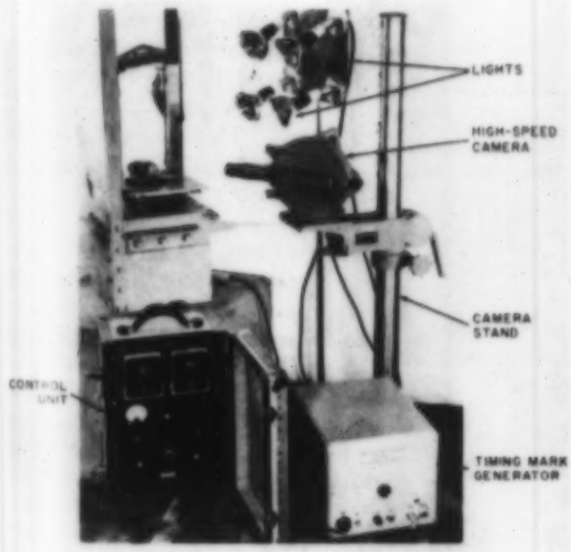

Fig. 1—High-speed camera set-up for analysis of vibration and shock

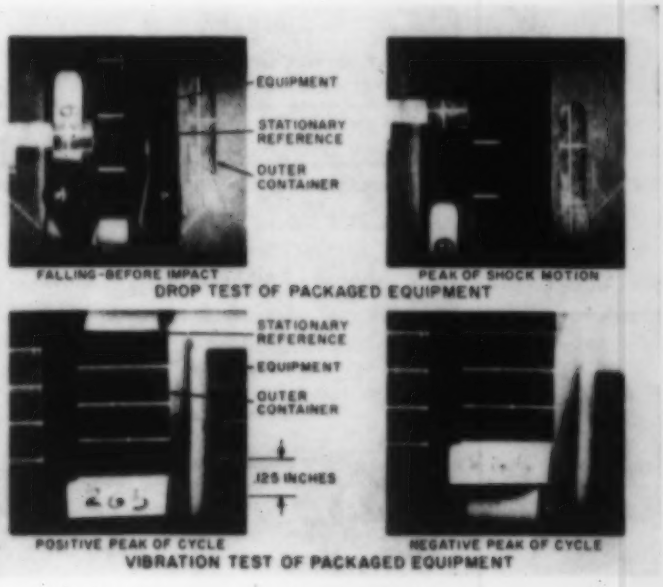

Fig. 2—Scenes from films made for vibration and shock measurement

enced operator may be five times as much.

Following the reading of the film, the information obtained is processed to get displacement-time data. Readings of distance on the film are converted to actual distance by multiplying by a scale factor. This factor can be determined by measuring a distance of known size in the film or it can be calculated with standard lens formulas if the focal length of the camera lens and the distance between the film plane and the subject were recorded when the film was taken. The readings which were recorded by frame number have to be related to the elapsed time. This is done by means of the timing marks on the edge of the film. Instead of calculating the elapsed time for each frame number, usually a plotting line is constructed on the displacement-time curve which relates frame number to elapsed time, *Fig.* 3.

If all the information desired from the film analysis is displacement data, then the displacement-time curves can be plotted in any convenient manner. If, however, accelerations are to be obtained, then particular attention must be paid to the manner in which the displacement-time curves are plotted and drawn. This stems from the fact that the acceleration, being the second derivative of displacement, is greatly affected by the smallest variation in displacement.

In the method of analysis described here, the acceleration is determined from the displacement-time curves. For a typical analysis of acceleration the displacement-time curves may have to be plotted so that the displacement readings can be estimated to the nearest 0.001-inch. For this purpose, where several inches of motion are involved, it is necessary to use large sheets of graph paper. The plotted points may have minor variations about the indicated curve which are due either to normal random error in the film reading process or to high-frequency variations which actually exist in the motion measured. In either case the curve is drawn smoothly following the basic motion indicated by the plotted points but not the minor point-to-point variations.

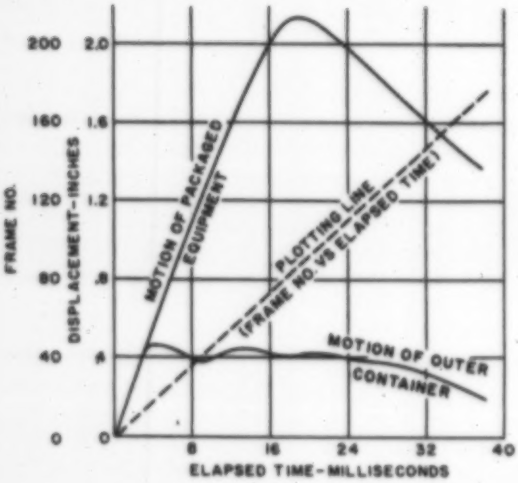

Fig. 3—Displacement-time curve for drop test of packaged equipment

ELAPSED TIME (MILLISECONDS)	DISPLACEMENT (INCHES)	VELOCITY (IN./.002 SEC)	ACCELERATION [IN./(.002 SEC)^2]	ACCELERATION (NO. OF G'S)
0	0			
		+.271		
2	.271		+.001	+07
		+.272		
4	.543		0	0
		+.272		
6	.815		+.002	+1.3
		+.274		
8	1.089		-.009	-5.9
		+.265		
10	1.354			

Fig. 4—Portion of a tabular form for determining acceleration by graphical differentiation

Velocities and accelerations are determined from the displacement-time curve by a process of graphical differentiation. This involves taking values of displacement from the displacement-time curve over equal increments of time and successively subtracting them to obtain the average value of slope or velocity over each increment of time. The values of velocity thus obtained are then successively subtracted to obtain values representing the change in velocity, or acceleration, *Fig.* 4. These values are plotted, and the result is a broken line curve of acceleration versus time with each point representing the approximate acceleration over its time increment, *Fig.* 5.

This process accurately shows the acceleration magnitude and pulse shape providing the time increment used is small in proportion to the period of the acceleration pulse. This again is related to the considerations of accuracy and frequency response.

Sample Film Analysis: Data taken from an actual film analysis of a drop test of packaged equipment is presented in ***Figs.*** 3, 4 and 5. The displacement-time curves, *Fig.* 3, show the motion of a container and of equipment protected by shock cushioning material inside a container. The curves begin shortly before impact of the container with the floor and end after the peak shock motion is over. The difference between the two indicates the amount of compression of the shock cushioning

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material. Note the plotting line which facilitates rapid plotting of values of displacement recorded by frame number without calculating the elapsed time. The plotting line may be curved if the film speed changes appreciably during the interval measured.

A portion of the tabular form used to determine velocity and acceleration from values of displacement taken from the displacement-time curve is shown in *Fig.* 4. In this case the time increment used is 2 milliseconds. Since displacement is in inches the resulting values of acceleration are in inches per 2 milliseconds interval squared. These are converted to "g's" in the last column before plotting the acceleration-time curve shown in *Fig.* 5. This particular film analysis indicated that the cushioning material was not performing satisfactorily, since most of the acceleration (or deceleration) occurred within a small portion of the total compression distance.

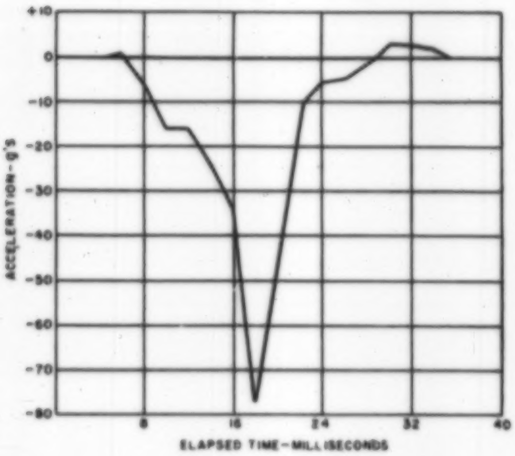

Fig. 5—Acceleration-time curve for drop test of packaged equipment

Ranges and Accuracies: To properly apply the film analysis procedure just described it is necessary to know ranges, limitations and accuracies of the results. Since all the data obtained by film analysis is based on displacement measurements, the limitations of the process are directly related to how accurately displacement can be measured. This depends on how much the subject photographed has been reduced in size on the film and on an error which is inherent in the film itself.

This film error has been evaluated and found to vary randomly from frame to frame between limits of ±0.0002-inch for measurements involving a distance of about ⅛-inch on the film. Most measurements are made over distances of less than ⅛-inch. This evaluation was made on a film with good focus and exposure, containing markers for measurement purposes. Thus with a scale factor of one (image size on film equal to object size), which is about the lowest value that it is practical to obtain, the displacement readings would be accurate to ±0.0002-inch. With a scale factor of 20 which is more common in packaging tests, the displacement readings would be accurate to ±0.004-inch.

Actual displacement-time curves can be drawn to greater accuracy if sufficient frames are read to show the error distribution of the plotted points about a mean line. Experience indicates in this procedure that a curve drawn along such a mean line has an error of one-fourth of the maximum error deviation of the points. It is this error upon which the rated accuracy of accelerations are based. To insure this accuracy there should be a minimum of ten readings for each cyclic variation that is to be shown; scales should be chosen to properly illustrate the variations described; and the curves should be drawn with the understanding of what maximum frequency is to be measured. The requirements for at least ten readings per cycle limit the frequency response where high accuracy is important to one-tenth of the maximum picture-taking rate of the camera. Thus with a 16-mm Fastax camera, the upper frequency for accurate measurement is 800 cycles per second.

From a paper entitled "High-Speed Motion Photography as a Tool in Shock and Vibration" presented at the SAE Aeronautic Meeting in Los Angeles, Calif., October, 1954.

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From a paper by H. R. Letner entitled "A Modern Perspective of the Grinding Process" presented at the ASME Fall Meeting in Milwaukee, Wis., September, 1954.

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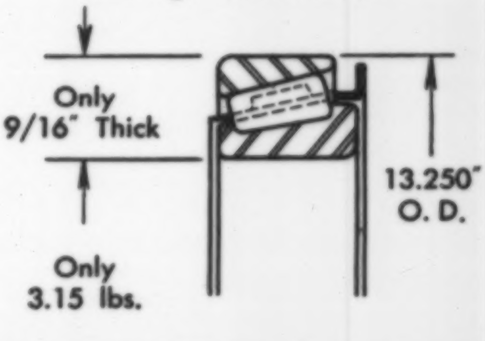

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Helpful Literature

(Continued from Page 222)

hardener HN-901, resin produces casting with great mechanical strength, resistance to high temperatures as well as to water and chemicals and good electrical properties at room and elevated temperatures.

35. Roller Gear Drives

Ferguson Machine & Tool Co., Roller Gear Div.—20-page catalog 105 on roller gear drives covers typical applications, selection procedure, nomenclature, calculation of load requirements, design of installation, drive selection data, component dimensions and standard housing dimensions. These precision cam indexing mechanisms can operate at over 1000 indexes per minute.

36. Motor Alternator

Electric Motors & Specialties, Inc.—Dimensions and performance data are provided in form HA-12-54 on model HA-2 30-cps motor alternator. Unit is used in synchronizing driven shaft rotation with two-phase electrical signals, in driving two-phase alternators and serving as an accurate phase standard. Motor and alternator are on the same shaft.

37. Stainless & Alloy Tubing

Trent Tube Co.—48-page plastic bound brochure tells the story of "Trentweld Stainless and High Alloy Tubing." Piece describes pressure, sanitary, aircraft, mechanical, heat resistant, ornamental, beverage and large diameter tubing with full specifications. Tubing ranges in size from ¼ to 40 in. OD. Tabulated data cover physical, chemical and electrical properties; theoretical weights; laboratory corrosion data; temperature conversion; and hardness equivalents.

38. Tracing Papers

Frederick Post Co.—Fact file on PTM, Post tracing medium, contains working samples with facts on such benefits as film-like transparency, evenly textured surface and dimensional stability. Samples include reproduction and tracing type paper and cloths.

39. Variable Speed Reducer

Revco Inc.—The Zero-Max speed reducer capable of taking one speed at input section and delivering infinitely variable speeds from output section is subject of descriptive 8-page booklet. Standard, reverse and special types are offered in torque ratings of 10, 15 and 20 lb-in., and horsepowers from 1/30 to ¼. Applications are pictured.

40. Short Run Stampings

Federal Tool & Mfg. Co.—"The Story of Federal Short Run Stampings" is title of 12-page brochure 15 which points up facilities, personnel and experience of this company. Stampings can be produced in any quantity from 2 to 10,000 pieces per order, in any shape or size from the smallest parts up to 10 x 14 in. and in any thickness up to ¼-in. within 125-ton maximum blanking capacity.

41. Aluminum Mill Products

Reynolds Metals Co.—Information contained in 16-page brochure on company's mill products and how to use them is based on new alloy designation system. Piece contains complete wrought aluminum alloy selection guide which outlines general properties of various aluminum mill products and lists their application. Casting alloy selection guide is included. Fabricating and finishing of aluminum are explained.

42. Worm Gear Sets

Foote Bros. Gear & Machine Corp.—24-page brochure catalogs standard line of worm gear sets available in standard ratios from 4¼ to 71. These worm gear sets find application in cranes and hoists, machine tools, furnace drives and metal mills, and other equipment with shock load or uniform load characteristics.

43. Control Switches, Timers

Zenith Electric Co. — Pocket-size 8-page pamphlet provides "Supplementary Listings" of transfer and remote control switches, contactors and program and interval timers.

44. Direct Current Motors

Barber-Colman Co.—Permanent magnet direct current motors with outputs up to 1/10-hp are described in catalog F 4344-1. Catalog contains data sheets on typical motors from 6 to 115 v dc. Units having radio noise filters, gear heads and centrifugal blowers are described. These units are suited to power electro-mechanical actuators, transfer switches and programming devices as well as for use as tachometer generators.

45. Engineering Service

Pioneer Engineering & Mfg. Co. — "One Source" is title of 8-page bulletin PE-25 which points up experience, facilities and ability behind a complete, single-source engineering service. Such services as product design and development manufacturing cost studies and production engineering are discussed. Company facilities devoted to engineering and design use are shown.

46. Rotary Solenoids, Relays

G. H. Leland, Inc.—Ledex rotary solenoids and stepping and selective relays are described in 6-page folder 354-RS&R. Solenoids are offered in seven basic models with various degrees of rotation and torque values up to 54 lb-in. Applications are pictured and dimensions and torque ratings are provided.

47. Fitting Caps & Plugs

Protective Closures Co. — CaPlug line of threaded and nonthreaded caps and plugs described in file folder are intended for safeguarding threaded ends of tubing, fittings, valves, hydraulic components and numerous machined parts. Enclosed in folder are price lists for over 100 stocked sizes of five standard plug and cap designs.

48. Properties of Teflon

Micromold Products Corp. — Outstanding properties of du Pont's Teflon and its many applications are listed in 6-page pocket-size folder 410. Properties pertain to chemical inertness, heat resistance, stability, moisture absorption, non-adhesiveness, resistance to arcing, electrical properties and friction coefficient.

49. Air Tube System

Lamson Corp.—How the prefabricated Airtube package will connect any two points up to 130 ft apart at either the same or different floor levels, and how it can be extended into a larger system is shown in 4-page catalog A-100. Booklet suggests variety of arrangements for installing equipment in any type building and provides instructions for laying out and installing a double-tube system.

50. High Pressure Equipment

American Instrument Co. — High pressure equipment described in catalog 406 embraces pilot plants, reaction vessels, valves, fittings, tubing, pumps, compressors, pressure balances, instruments and accessories. Equipment is designed for pressures to 10,000 psi and temperatures to 1000° F.

51. Variable Speed Drives

Standard Transmission Equipment Co.—Operating on the adjustable-pitch pulley principle, CUB and JFS-Jr. variable speed transmissions are available with 3.3 to 1 and up to 10 to 1 speed ranges with ratings up to 5 hp. Details of these drives and complete selection tables are contained in 4-page illustrated bulletin.

52. Cylinder Boring Facilities

American Hollow Boring Co.—Facilities of this company for the boring and honing of cylinders and shafts to exacting specifications are outlined in 4-page illustrated bulletin HC-1. Production capacities range in inside diameters from 1¼ to 15 in. and lengths to 27 ft.

53. Fast-Machining Steels

Joseph T. Ryerson & Son, Inc.—"Guide to Selection of Fastest Machining Steels" is a 4-page illustrated comparative study of leaded carbon and alloy steels which are fast machining and free-cutting. Relative machinability, using B-1112 as standard, of fast-cutting carbon, alloy and stainless steel is compared. Other principal characteristics of 17 different analyses are summarized.

54. Cast Stainless Alloy

Alloy Casting Institute—26-page illustrated set of data sheets is compilation of properties of all of the more popular grades of alloys used for corrosion resisting castings. Data have been collected in cooperation with such other groups as the ASTM and SAE. Each of 13 data sheets lists chemical compositions, physical properties, mechanical properties and includes a discussion of design considerations.

55. Air Release Valves

V. D. Anderson Co.—Illustrated condensed bulletin B-654A discusses the purpose, method of operation, applications, sizes and capacities of line of air release valves. Six sizes are available with capacities from 6.2 cfm at 5 psi to 165 cfm at 250 psi.

56. Aluminum Base Alloys

Apex Smelting Co.—Properties of Ternalloy, aluminum base alloy series for high-strength castings without heat treatment, are listed in 8-page illustrated file folder. Included is complete engineering information on mechanical and physical properties, together with a discussion of its castability and machinability.

57. Fluid Pressure Switches

Aircraft Controls Co.—Both metallic diaphragm and metallic bellows type are included in line of aircraft fluid pressure switches described in 4-page illustrated bulletin 101. All meet basic Army, Navy and Air Force standards. Pressure, high and low differential pressure, altitude and other special purpose switches are described, along with float switches.

58. Jacketed Pumps

Viking Pump Co.—Jacketed positive displacement pumps, designed with only two moving parts, are described and illustrated in the 10 pages of plastic-bound catalog section E. They maintain uniform hot or cold temperature and are offered in 90 to 485 gpm capacities, in a variety of drives and metals. Design features and detailed specifications are given.

59. V-8 Gasoline Engine

Chrysler Marine & Industrial Engine Corp.—4-page illustrated specification sheet lists specifications and tabulates performance of the model 24 V-8 industrial gasoline engine which has 331 cu in. displacement and develops 183 hp at 4000 rpm. Engine is available separately and as open or enclosed packaged power units.

60. Vinyl Butyral Resins

Bakelite Co.—Properties and applications of Bakelite vinyl butyral resins are treated in 28-page illustrated manual No. 11. These resins are widely known for their part in making safety glass possible. They are finding application in wash primers or metal conditioners, wood and metal finishes, adhesives and cloth coatings.

61. Hydraulic Control Valves

Denison Engineering Co.—20-page illustrated bulletin VR-2C is descriptive of complete line of relief, sequence, unloading and pressure-reducing valves for service up to 5000 psi. Unusually fast acting, with a low differential between opening and closing pressures, these adjustable controls afford accurate pressure regulation and close control of pressures throughout a hydraulic system.

62. Instrumentation Engineering

Consolidated Engineering Corp.—Custom engineering of electronic instrumentation to specific industrial, scientific and military needs is subject of 16-page illustrated brochure CEC-1304. It depicts the role of this company's newly formed Systems Division in developing and producing entire systems for automatic data processing and control. Case histories of typical instrumentation systems are cited.

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417 PIQUETTE AVE., DETROIT 2, MICH. • GENERAL SALES OFFICES: ST. PAUL 6, MINN. • EXPORT: 99 PARK AVE., N.Y. 16, N.Y. • CANADA: P. O. BOX 757, LONDON, ONT.

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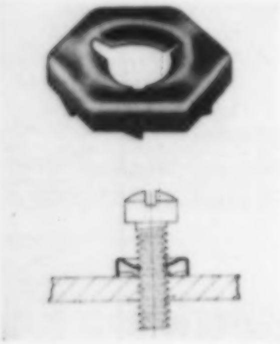
NEW PARTS AND MATERIALS

For additional information on these new developments, see Page 221

Tension Type Locknuts

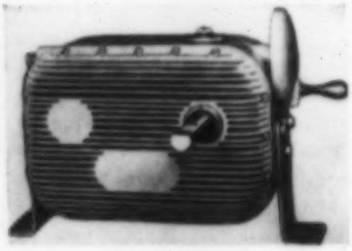
Use of this tension type locknut permits changing the setting of an adjusting screw to any desired position. Barbs at base of nut grip and hold securely. Once fastener is assembled, repeated screw adjustments can be made without need for changing position of the nut. Fastener exerts a resilient spring locking action on the threads of the adjusting screw and prevents it from turning under any condition of vibration. Back-off torque is twice installation torque. Available sizes are No. 2-56, 4-36, 6-32, 6-56 and 10-32. Made by **Palnut Co.,** 61 Cordier St., Irvington 11, N. J.



For more data circle MD-63, Page 221

Variable Speed Drive

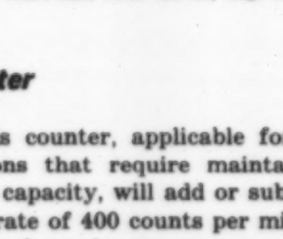
Model 24 Zero-Max infinitely variable speed reducer has a constant output torque rating of 100 lb-in. or ¾-hp at 450 rpm. Full variable speed is provided from zero to one-fourth of the input speed. Four-way mounting brackets simplify installation. Desired output speed is selected by means of a screw handwheel, and speed changes can be made while unit is operating. Made by **Revco Inc.,** 2 E. Franklin Ave., Minneapolis 4, Minn.



For more data circle MD-64, Page 221

Counter

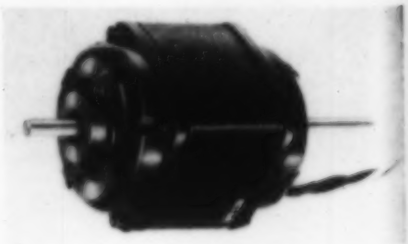
This counter, applicable for operations that require maintaining a set capacity, will add or subtract at a rate of 400 counts per minute, up or down in any sequence, one count per impulse, to a maximum of 999. It can be set at a predetermined figure to shut off at zero automatically. Unit measures 3½ x 6½ x 6½ in. and weighs 2 lb 5 oz. Electrical coils are intermittent duty, rated 6 to 110 v ac. Actuation can be by photoelectric cell, tube, relay or contact switch. Made by **Spencer Mfg. Co.,** 3253 N. Cicero Ave, Chicago 41, Ill.



For more data circle MD-65, Page 221

Sleeve Bearing Motor

Vertically mounted model RCS-65 sleeve bearing motor is permanent split-capacitor type, measuring 2 9/16 in. in diameter. It may be safely operated at high output torque when provided with a small fan for cooling, opposite the drive end. Torque rating is 4 oz-in. at approximately 1650 rpm on 115 v, 60 cycles, continuous duty. The stray magnetic leakage field is low. Made by **National Pneumatic Co. Inc.,** Holtzer-Cabot Motor Div., 125 Amory St., Boston 19, Mass.



For more data circle MD-66, Page 221

Rotary Switches

Series of small rotary switches with dual coaxial spindles provides control of a second switch, thermostat, solenoid, damper, valve or other electrical or mechanical unit. Model 3900 switches have UL-approved ratings up to 20 amp at

Specify

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"Economy . . . counts not in savings but in selection."—*Edmund Burke*

Economy through Efficiency

Gits Unit Seal proves itself in dependable performance over a wide range of operating conditions—including extra-high speed, heat and pressure applications. Operation at peak efficiency always means dollars-and-cents savings.

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Gits Unit Seal fits many applications as a standardized item actually carried in stock. You harness the savings of mass production to your own specific needs. Gits Unit Seal already has wide application in the following fields: Washing Machines, Disposal Units, Gear Motors, Speed Reducers, Aircraft Turbine Pumps, Accessory Drive Units, Jet Propulsion Units, Electrical Power Equipment, Automotive Accessories, Business Machines, Standard and Special Machine Tools.

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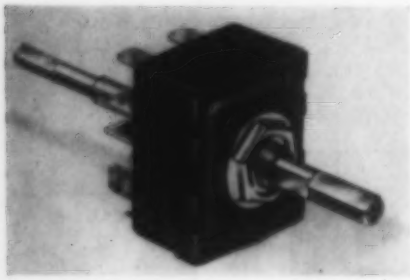
"Cartridge Seal" requiring only 25% more space than lip-type seals.

GITS BROS. MFG. CO.

1868 S. Kilbourn Avenue
Chicago 23, Illinois

120 or 240 v and ½, ¾ and 1 hp at 120 v. Smaller direct current ratings are also available. Outer shaft of the spindle controls the switch itself, while the inner shaft, extending through the rear of the base, provides for independent operation of auxiliary equipment. Switches are available single or double-pole, 2 to 12 positions, with stop as required. Size is 1½ x 1¼ x ⅞-in. Made by **Hart Mfg. Co.,** 110 Bartholomew Ave., Hartford, Conn.

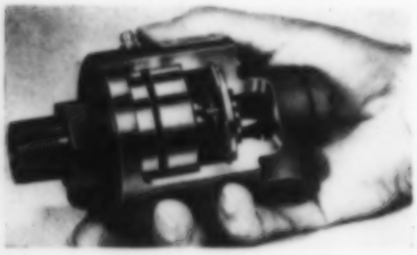


For more data circle MD-67, Page 221

Rotating Union

Compact rotating unions for water and steam service to 300 F are intended for cooling or heating high-speed rotating shafts, drums and cylinders. The ¾-in. union illustrated is double-purpose in that all component parts are alike for both ½ and ¾-in. service, with exception of the rotors. Union can also be changed over from through operation to entrance and return connection on the same side.

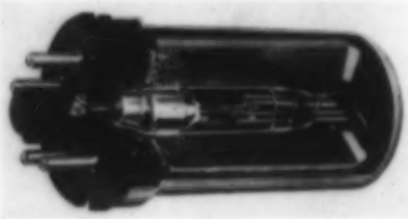
Alternate rotors for model 250 are offered with ½-in. left or right-hand pipe threads, ¾-in. right or left-hand threads and 1-in.-14 N.F. right or left-hand machine threads. A 1-in.-14 N.F. right hand pilot type rotor is offered for applications where close concentricity is required. Model 450 is available with 1¼ and 1½ right or left-hand pipe threads. Snap ring assembly facilitates quick repair in the field. Made by **Deublin Co.,** 1155 Waukegan Rd., Glenview, Ill.



For more data circle MD-68, Page 221

Contact Relays

Type HG and type HGP relays, designed for use in high-speed switching machines and devices, will operate up to 60 times a second. They have current-carrying capacity up to 5 amp and voltage-handling capacity up to 500 v. Relays withstand vibration. Uniformity of operation is kept to within 1.5 millisecond under constant drive conditions. Platinum contact surfaces are continuously wetted with mercury by capillary action.



Magnetic switch is hermetically sealed in a protected glass capsule, pressurized with hydrogen. Illustrated cutaway view of the type HG relay shows the mercury-wetted contact switch sealed in glass. The glass capsule is surrounded by the operating coil and encased in a metal housing mounted on an octal base. Type HGP relays are similar but can be factory-adjusted to provide either biased or polarized operating characteristics. Made by **C. P. Clare & Co.,** 3101 Pratt Blvd., Chicago 45, Ill.

For more data circle MD-69, Page 221

Quick-Exhaust Valve

Efficiency and operating speed of air cylinders are increased by this quick-exhaust valve, which provides fast venting of air from the return side. Compactness of valve permits installation at the cylinder inlet. Finished in zinc and chromate plating, it is available with ⅜-in. pipe ports. A silencer is available. Made by **Air-Mite Devices Inc.,** 4417 W. Carroll Ave., Chicago, Ill.

AIR-MITE
CHICAGO
CYL

For more data circle MD-70, Page 221

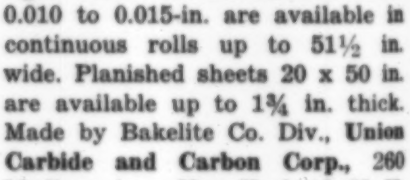
Polyvinyl Chloride Sheet

Bakelite rigid polyvinyl chloride sheet has high impact, tensile, flexural and welding strength. Sheet is self-extinguishing and combines high chemical and moisture resistance with heat distortion point of 160 F. Tests indicate sheet withstands 750 to 1000 hours of intense sunlight before blackening. Both natural unpigmented and opaque rigid sheet in thicknesses from 0.010 to 0.015-in. are available in continuous rolls up to 51½ in. wide. Planished sheets 20 x 50 in. are available up to 1¾ in. thick. Made by Bakelite Co. Div., **Union Carbide and Carbon Corp.,** 260 Madison Ave., New York 16, N. Y.

For more data circle MD-71, Page 221

Accumulator

Maintenance of constant pressure, compensation for fluid leakage in hydraulic systems and elimination of shock and surges are provided by this cylindrical double-shell separator type accumulator. It incorporates a floating piston which transmits the pressure of precharged gas to the working medium and prevents entrainment



HYDRAULICS FOR
MOBILE EQUIPMENT

VOL.2

Mobile Equipment News

VICKERS INCORPORATED, DETROIT, MICHIGAN

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PERFORMANCE
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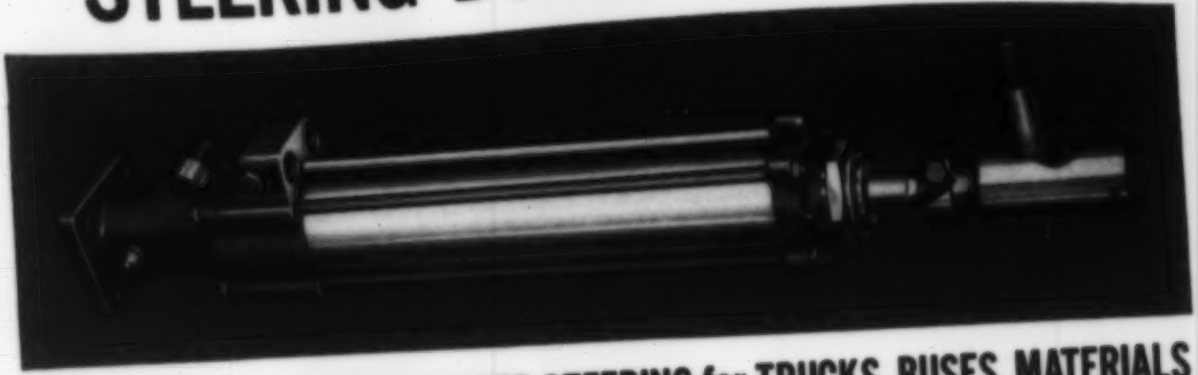
CUTS COSTS

NO. 5

New! VICKERS® HYDRAULIC POWER STEERING BOOSTER...SERIES S23



LATEST DEVELOPMENT in POWER STEERING for TRUCKS, BUSES, MATERIALS HANDLING VEHICLES, ROAD CONSTRUCTION and MINING MACHINERY

More compact . . . improved in operating characteristics . . . this new Vickers Steering Booster, Series S23 is an important new development in power steering for many vehicles. Application is much easier because it requires less space . . . and ultimate costs are substantially lower. Series S23 thus opens the way to fingertip ease of steering for a wide range of additional vehicles.

Like the preceding models, Series S23 has hydraulic lock against road shock. Bumps, chuckholes, blown front tires, obstructions, etc., cannot spin the steering wheel or jerk it out of control. This is a safety factor of great importance.

Series S23 Boosters are provided either with (Model S23R) or without (Model S23N) an integral relief valve. Model S23N is used with Vickers VT16 and VT17 pumps that have integral volume control and relief valve. When the larger volume Series V200 pump is used and a volume control is required in the circuit, the S23N is used with a separate combination valve (see Series FM2 below). Model S23R is used with the Series V200 pumps that have no integral valving, for applications where a volume control is not required.

ASK FOR NEW BULLETIN M5106

MORE VERSATILE INSTALLATION

In Series S23 Boosters, the servo ball stud housing is symmetrical, and can be assembled in any one of four positions. This and the compactness of the Booster makes application easier . . . increases the number of applications which can be made without major engineering changes. Series S23 Boosters can be mounted interchangeably with Models S6-277 and S6-279 Boosters.

REQUIRES LESS SPACE

The new booster has been reduced in size by the redesign of the servo control valve. The tube connecting the servo valve to the rod end has been relocated and is now on the same side as the fitting connection. As a result of these changes, Series S23 requires less space . . . works in closer quarters.

7062

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VICKERS® VOLUME CONTROL and OVERLOAD RELIEF VALVE

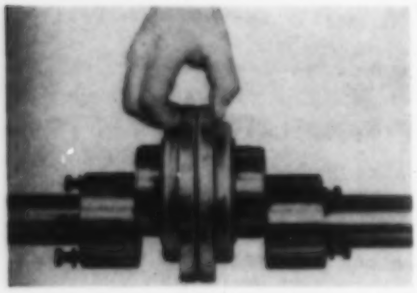
Five sizes of Series FM2 Valves were developed primarily for hydraulic power steering on trucks, buses and materials handling equipment where the pump does not include a volume control valve. The FM2 improves steering booster performance by providing a relatively constant volume of oil regardless of engine speed variations. An integral relief valve is included.

ENGINEERS AND BUILDERS OF OIL HYDRAULIC EQUIPMENT SINCE 1921 of gas into hydraulic fluid. A dashpot decelerates piston travel to eliminate piston hammering. Units are designed for 2000 psi and will deliver 2310 cu in. of oil with pressure drop of 10 per cent and hold a net gas capacity of 21,950 cu in. Made by **Superior Pipe Specialties Co.,** Superior Hydraulics Div., 15201 St. Clair Ave., Cleveland 10, O.

For more data circle MD-72, Page 221

Flexible Shaft Coupling

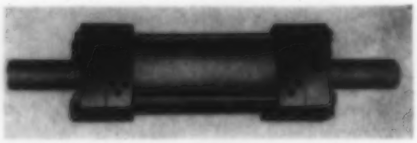
Spacer type flexible shaft coupling is intended for use on installation with more than a normal gap between the connected shafts. Installed or removed without disturbing either the driving or driven unit, type F Steelflex Spacer coupling can be used on any application with a gap up to 12 in. Coupling provides protection against damage from impact loads and shaft misalignment. Prelubricated unit requires grease gun maintenance lubrication once every 6 months. Coupling is offered in 15 models for 11/16 to 7-in. shaft sizes for maximum speeds from 3600 to 2100 rpm. Made by **Falk Corp.,** Dept. 361, 3001 W. Canal St., Milwaukee 8, Wis.



For more data circle MD-73, Page 221

Air-Hydraulic Booster

Capable of delivering an unlimited amount of high pressure fluid for operation of hydraulic cylinders and equipment, this continuous-action reciprocating air-hydraulic booster operates from plant air compressor. Consisting of a double-rod end air cylinder with a hydraulic discharge pressure chamber at each end, the booster delivers a pressure output stroke in both directions. It is available in ratios to give pressures to 10,000 psi and over. The 25 to 1 ratio unit produces 2000 psi hydraulic output from 80-psi air input. It consists of a 5-in. diameter air piston driving two 1-in. diameter hydraulic rams, each having a 6-in. stroke. Hydraulic pressure is continuous. Made by **Miller Fluid Power Co.,** 2040 N. Hawthorne Ave., Melrose Park, Ill.



For more data circle MD-74, Page 221

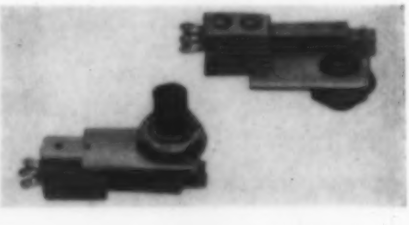
Vinyl Paint

Vinyl and other plastic resins are combined in Tygon ATD hot-spray-applied protective coating to form a high-solids content viscous material that builds a film thickness in two coats equal to five coats of a cold-spray vinyl coating. Dense and impermeable coat of 3-mil thickness can be built up in one application. Paint is resistant to the attack of most commercially used acids and alkalies, as well as alcohols, water and oils. It is, however, attacked by aromatic hydrocarbons, ketones and esters. Made by **U. S. Stoneware Co.,** Akron 9, O.

For more data circle MD-75, Page 221

Flat-Frame Switches

Utilization of a small spring results in small overall size of flat-frame NF-Switches. The flat frame is readily adaptable to any stacking of contact springs to provide a simple, direct-acting push-button switch. Modification and combinations of contact springs make switch adaptable to most requirements. Fine silver contacts are rated at 3 amp, 120 v ac, noninductive load. Switch also can be made with welded cross-bar palladium contacts for low-level circuits. Seven standard circuits are available, with Form A, Form B, Form C, 2 Form A, 2 Form B, 2 Form C, or 3 Form C contacts. Made by **Switchcraft Inc.,** 1328 N. Halsted St., Chicago 22, Ill.



For more data circle MD-76, Page 221

Yarn Packing

Antifrictional properties of Teflon, combined with softness, resilience and fluid retaining properties of fiber yarn enables this packing to run cool at high peripheral speeds. Packing is tightly braided for density and firmness. Where lubrication is required, it can be impregnated with fluorolube or other materials. Available in ⅛ through ⅝-in. sizes, in 1/16-in. graduations, packing is suitable for pump shafts and valve stems handling corrosives. Made by **Crane Packing Co.,** Dept. MDC, 1800 Cuyler Ave., Chicago 13, Ill.

For more data circle MD-77, Page 221

Weld and Clinch Nuts

Both pilot type and countersunk Gripco weld nuts, as well as hexagon pilot clinch nuts, are now available in stainless steel. Nuts are offered with and without Gripco self-locking feature. Sizes available at present are 10-32 through ¼-in. fine and coarse threads. In the near future 5/16 and ⅜-in. sizes will be available

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Continental Produces Over 1,756,000 Styles and Sizes of Standard Screws Alone!

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The vast inventory of fastenings offered by Continental is proof that you can always count on Continental for every fastener need. Whether your demands are for special or regular units, you will be assured of the best fastener for your job and of fast service, too.

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Continental Screw Co.

Manufacturers of Holtite Fastenings

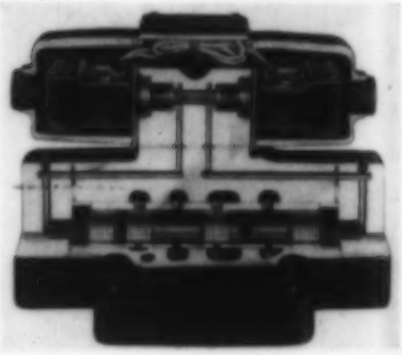
NEW BEDFORD, MASSACHUSETTS, U. S. A.

in both fine and coarse threads. Made by **Grip Nut Co.**, 310 S. Michigan Ave., Chicago 4, Ill.

For more data circle MD-78, Page 221

Four-Way Valve

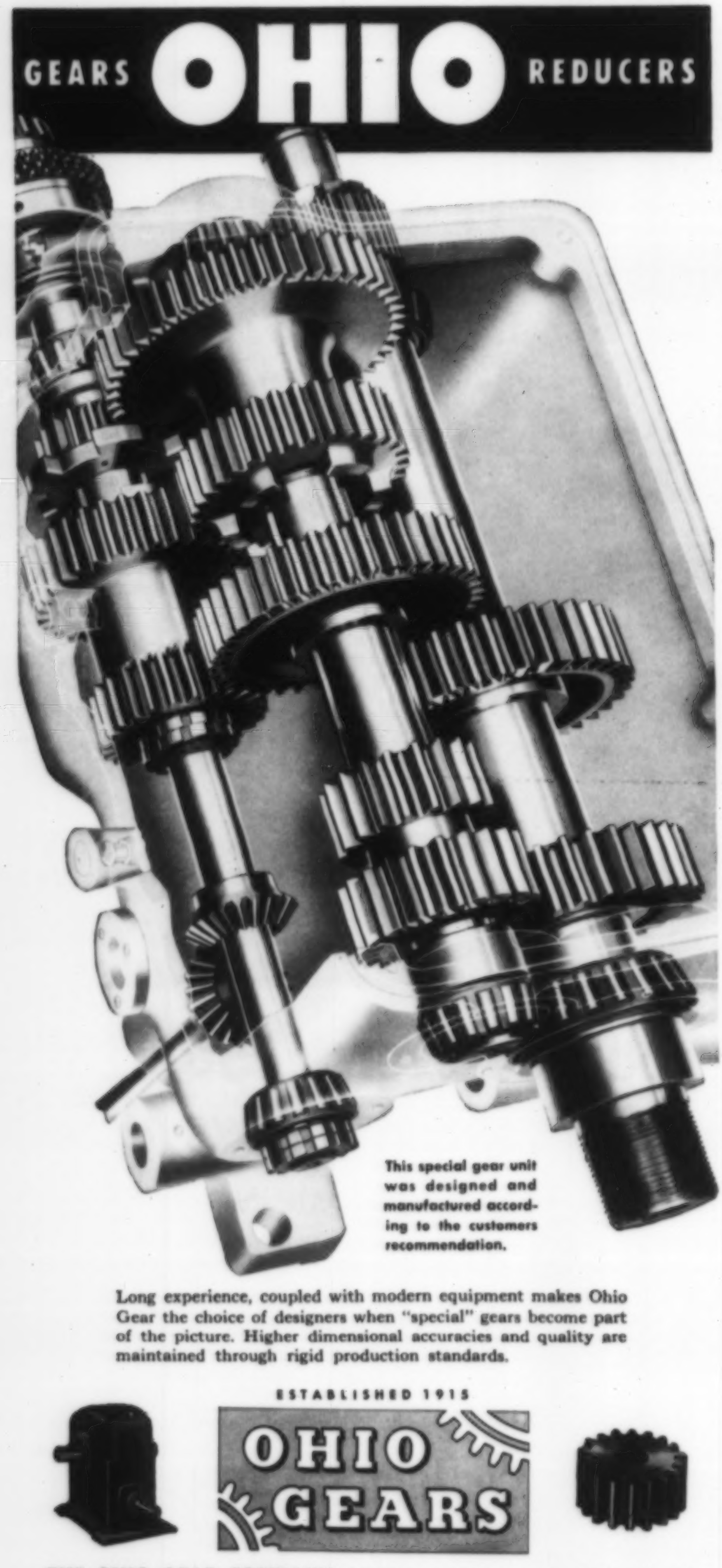
Bulletin 59-S ¾-in., balanced piston, sleeve type four-way valve is solenoid controlled and pilot operated. It can be operated at pressures to 2000 psi. Spring-centered, spring-offset and no-spring models can be readily converted from one type to another. Twin solenoids have compact, concealed dustproof housing. They are fastened to the valve by the cover only. When covers are removed, electrical operation cannot be made. Mounting of valve is by means of a subplate. Made by **Racine Hydraulics & Machinery Inc.**, 2000 Albert St., Racine, Wis.



For more data circle MD-79, Page 221

Protected AC Motors

Totally-protected ac motors have solid cast frames and plastic sleeving that protects brazed coil head connections inside the motor. Regardless of mounting position, motor is protected against drip, splash and falling objects. Ventilation louvers are in the end brackets. The frame extends beyond the coil heads to protect the windings. Neoprene gaskets afford a positive seal between the frame and conduit box, and these gaskets have



This special gear unit was designed and manufactured according to the customers recommendation.

Long experience, coupled with modern equipment makes Ohio Gear the choice of designers when "special" gears become part of the picture. Higher dimensional accuracies and quality are maintained through rigid production standards.

THE OHIO GEAR COMPANY, 1338 East 179th St., Cleveland 10, Ohio

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specify LELAND

No product is any better than its components . . . no motor any better than what went into it – in design, materials, in craftsmanship.

And Leland's policy has always been to *go beyond* minimum requirements . . . to give you the *extra* value that *assures* dependability, that *surpasses* mere customer "satisfaction"

It has meant painstaking, creative design. Often the use of finer materials. Always more rigorous quality control. But that policy has proved successful because users *know and appreciate* the extra value a Leland motor offers.

Look for more than "satisfaction" from the motors *you* specify, buy or use. It costs you no more . . . it does mean a finer, more reliable product.

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high performance
SHAKER
in CALIDYNE'S
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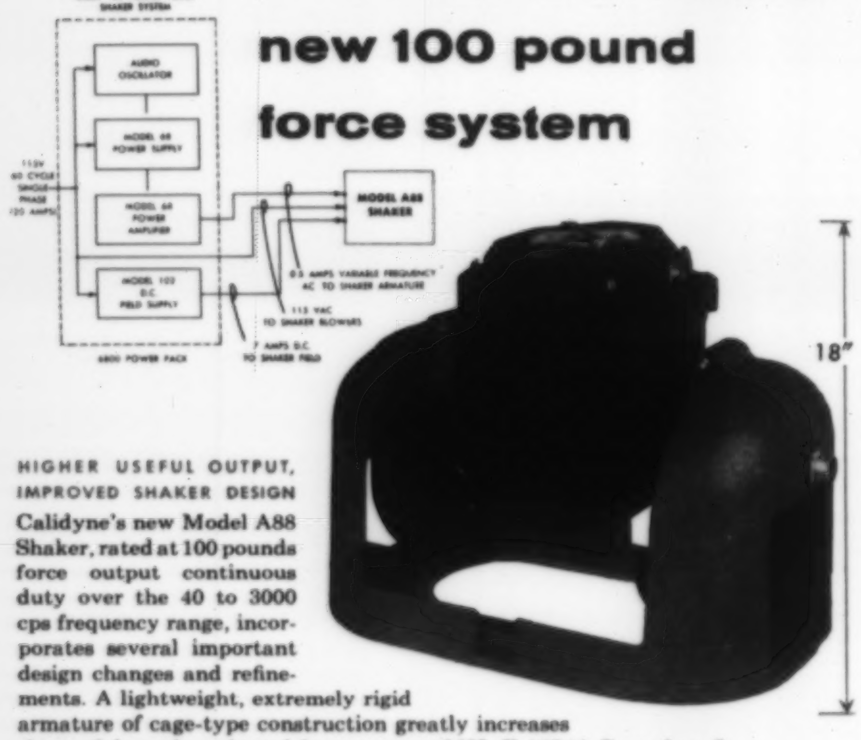
force system


BASIC 100 POUND FORCE SHAKER SYSTEM
AUDIO OSCILLATOR
MODEL 68 POWER SUPPLY
MODEL 68 POWER AMPLIFIER
MODEL 102 D.C. FIELD SUPPLY
6800 POWER PACK
115V 60 CYCLE SINGLE PHASE 120 AMPS
MODEL A88 SHAKER
0.5 AMPS VARIABLE FREQUENCY AC TO SHAKER ARMATURE
115 VAC TO SHAKER BLOWERS
7 AMPS D.C. TO SHAKER FIELD
18"

HIGHER USEFUL OUTPUT,
IMPROVED SHAKER DESIGN

Calidyne's new Model A88 Shaker, rated at 100 pounds force output continuous duty over the 40 to 3000 cps frequency range, incorporates several important design changes and refinements. A lightweight, extremely rigid armature of cage-type construction greatly increases the useful portion of total force output. MIL-E-5272A Procedure I requirements, for example, can be met with mass loads up to 7.3 pounds. Also, a new flexure system insures truly *linear* motion of the armature, and trunnion mounting of the Shaker allows forces to be exerted in any direction. And for monitoring amplitude of vibratory motion, a calibrated velocity signal generator has been built into the Shaker.

SINGLE CONSOLE CONTAINS CONTROLS AND POWER PACK

The 6800 Control and Power Pack unit includes the Power Amplifier, Audio Oscillator, and Shaker Field Supply, as well as all controls and indicators, for operation of the complete system. Accessories for monitoring Shaker vibratory levels and performing automatic cycling tests required in many MIL and JAN specifications may be added to the basic system at any time, by rack mounting in the cabinet.

Complete System Specifications and Details
Available on Request

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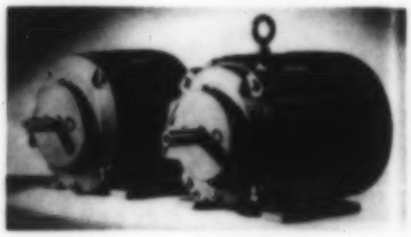
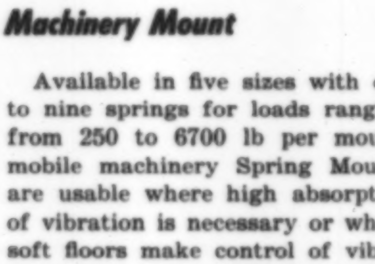


indexed "pressure knobs" to hold each lead securely. Fan-cooled, corrosion resistant and explosion-proof enclosed motors are available. Fan-cooled models have corrosion resistant outer fans and cast iron conduit boxes; corrosion resistant motors have Neoprene shaft slingers and optional stainless steel components; explosion-proof motors have brass shaft slingers, affording five-direction labyrinth fits. Made by **Reliance Electric & Engineering Co.,** 1088 Ivanhoe Rd., Cleveland 10, O.

For more data circle MD-80, Page 221

Machinery Mount

Available in five sizes with one to nine springs for loads ranging from 250 to 6700 lb per mount, mobile machinery Spring Mounts are usable where high absorption of vibration is necessary or where soft floors make control of vibration frequencies difficult. They are particularly adaptable to low speed, high impact applications. Each mount has a built-in adjustment which permits leveling up to ¾-in. Machines can be installed and leveled within a matter of minutes because machines need not be bolted or shimmed. Friction brake linings damp horizontal movement. Simple damping adjustments can be made to prevent sudden spring recoil when mount



is subjected to heavy impact and shock and when mounted unit goes through resonance. This checks excessive machine motion and bounce. Made by **Barry Corp.**, 700 Pleasant St., Watertown 72, Mass.

For more data circle MD-81, Page 221

Handwheels

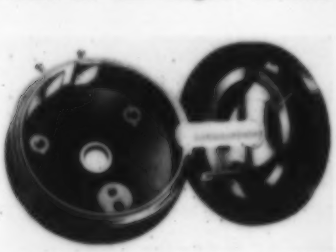
Solid aluminum alloy disk handwheels have finished outside diameter, with boss faced off and spot centered. Additional machining

can be specified. Wheels are available in 4 and 5-in. sizes, designed for easy attachment of revolving handles. Made by **Jergens Tool Specialty Co.**, 712 E. 163rd St., Cleveland 10, O.

For more data circle MD-82, Page 221

Potentiometers

Seventeen stock resistance values covering the range from 2 to 500,000 ohms in power rating from 2 to 20 w at 40 C ambient are in-included in eight models of 970 series wire-wound potentiometers. Independent linearity is from ±0.2-per cent on the largest models to



±2 per cent on the smallest. Resolution is from less than 0.05 to 1 percent. All models are totally enclosed, with capacitance kept low by use of phenolic body and cover and glass-reinforced polyester shaft. All models can be nested with spacing rings for low capacitance ganging with independent

(Continued on Page 240)

Cramer

TIME TOTALIZER

a highly accurate electrical stop clock . . .

1/100 OF A SECOND
100
10
20
30
40
50
60
70
80
90
60
SECONDS
5
10
15
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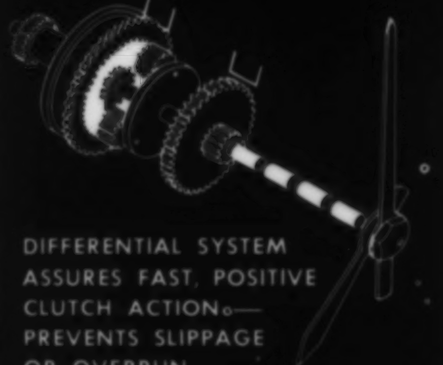
55

Type 690 . . .



DIFFERENTIAL SYSTEM ASSURES FAST, POSITIVE CLUTCH ACTION— PREVENTS SLIPPAGE OR OVERRUN.

Positive engagement of pawl with gear combined with fine gear teeth provides the instant response necessary for a timing accuracy of ± .01 seconds on the 60-second timer, and ± .005 minutes on the 60-minute unit.

On the dial face, a large sweep hand makes possible fast, exact readings from the outer scale, while an accumulator pointer records larger time units on a separate scale in the center of the dial.

This compact unit is available for AC or DC operation in commercial and military applications. It is used in laboratory experimentation, for testing communications equipment and systems, and in the field of nuclear research, as well as for timing critical industrial processes.

For complete information on the Type 690, write for bulletin PB-610.

Cramer TIMING DEVICES

SPECIALISTS IN TIME CONTROL

The R. W. CRAMER CO., Inc.

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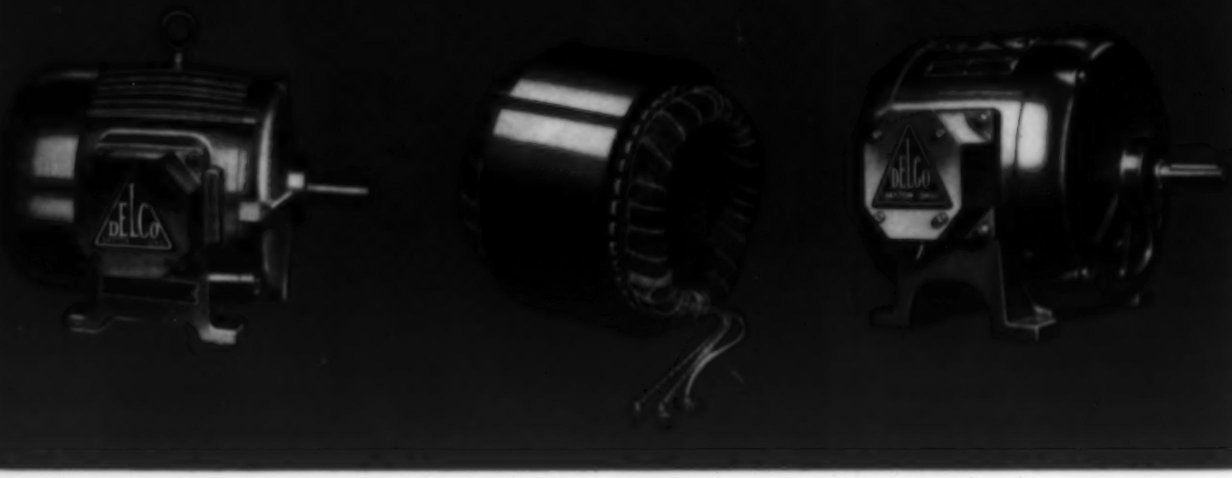
DAYTON OHIO

Delco
Electric Motors

a complete Line of



"The lady who is wise will ask to be advised if it's powered with a Delco Electric Motor."

Delco Electric Motors give you peak performance with complete dependability because each one is "job-fitted" to your most exacting requirements. Job-fitted means Delco *engineers* work with *your engineers* to make certain the application is absolutely right. This famous Delco Products service is your assurance that

★ ***Watch for Delco Motors national advertising in The Saturday Evening Post and Better Farming.***

will do a Better Job when

"Job Fitted" Power Them

Fractionals and Integrals

your products will consistently operate with maximum efficiency. It means the Delco Electric Motors that power your products will deliver topnotch service over longer periods of time : : . at less cost for maintenance.

You can be just as sure of another kind of dependability, too, whenever you work with Delco . . . *dependability of delivery*. Volume producers know Delco will deliver on time. Whatever the size of your order, wherever and whenever you want them, your motors will be there on schedule. And wherever your products go, throughout the world, Delco parts and Delco service facilities are always nearby.

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DELCO *Electric* MOTORS

DELCO PRODUCTS, DIVISION OF GENERAL MOTORS, DAYTON, OHIO

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CATALOG 55

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Horsburgh & Scott's new catalog provides you with all the information necessary for the proper selection of speed reducers.

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THE HORSBURGH & SCOTT CO.
GEARS AND SPEED REDUCERS
5112 Hamilton Avenue
Cleveland 14, Ohio

New Parts

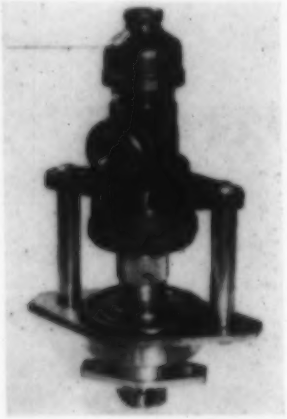
(*Continued from Page* 237)

phasing adjustment. Made by **General Radio Co.**, 275 Massachusetts Ave., Cambridge 39, Mass.

For more data circle MD-83, Page 221

Rotating Joint

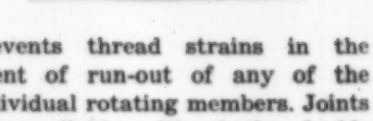
This double-passage rotating joint is a complete packaged unit which can be installed in equipment handling either air or hydraulic pressure and where two or more members must be rotated inside each other. Construction prevents thread strains in the event of run-out of any of the individual rotating members. Joints are available with single, double or triple rotating passages. They require no packing. Joints can handle different media through the different rotating passages at the same time. They are available with connections $\frac{1}{4}$-in. and larger. Made by **Rotherm Engineering Co. Inc.**, 7280 W. Devon Ave., Chicago 31, Ill.



For more data circle MD-84, Page 221

Bellows Coupling

Stainless steel bellows coupling joins shafts having either the same or different diameters. Used where



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"The Quiet Life"
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For moderate counting duty, where extreme long life is not required, this new small reset counter is completely reliable. Compact and easily connected, this counter may be actuated by any type of switch, relay or photoelectric unit. Recommended speed is 700 counts per minute. Power consumption is low . . . *and so is the price* . . . but still the same Veeder-Root high quality. So here again is proof that you can count on Veeder-Root for any type of counter . . . electrical, mechanical or manual . . . for any type of duty in any field from atomics to electronics. What do *you* need to count? Write:

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HARTFORD 2, CONNECTICUT

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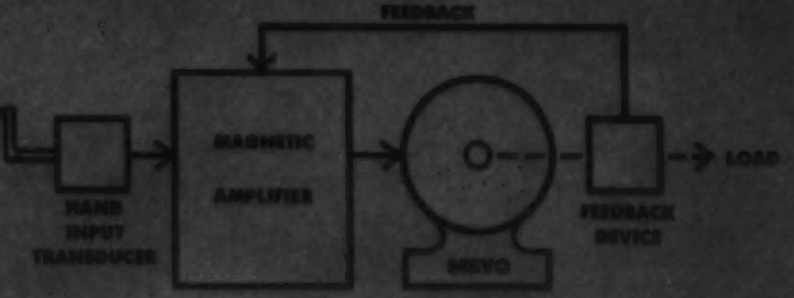
"The Name that Counts"

SINCE 1915 LEADERS IN AUTOMATIC CONTROL

Magnetic Amplifier SERVO SYSTEMS In the Horsepower Range



The task called for a rugged, reliable drive of a motor which would deliver up to four horsepower on acceleration, and at least 1½ horsepower continuously. Maintenance requirements to be at a minimum. The drive must be able to stand high shock and operate under several G's. It must operate in temperatures from –65° to 165°F.

Ford engineers developed such a drive in a magnetic amplifier servo system. It could be made for position control or rate control, and it operated smoothly and accurately under an unbalanced load condition. The gain or current-output/current-input (with motor stalled) = 60,000; with a maximum output of over 90 amps.

This is typical of the solution of engineering problems in the field of servomechanisms by the Ford Instrument Company. Should you have a problem such a solution may answer for you, write and indicate your needs. Ford Instrument Company's forty years of experience in developing, designing and manufacturing special devices in the field of automatic control will help you find the answer.

56

FORD INSTRUMENT COMPANY
DIVISION OF THE SPERRY CORPORATION
31-10 Thomson Avenue, Long Island City 1, N.Y.

ENGINEERS
of unusual abilities can find a future at FORD INSTRUMENT COMPANY. Write for information.

only low torque operation is required, the coupling permits a reasonable degree of angularity and misalignment. It is designed for basic shaft sizes of ⅛, 3/16 and ¼-in. and has stainless steel setscrews for holding and sub-drill holes for fixed pinning as desired. Various shaft-to-shaft combinations are available from stock; special designs can be furnished. Made by **PIC Design Corp.,** 160 Atlantic Ave., Lynbrook, L. I., N. Y.

For more data circle MD-85, Page 221

Hose Clamp

General purpose hose clamp, affixed in three seconds with pincers, stays in place on hose subjected to extreme internal pressure, movement and hard usage. Clamp is round with U-shaped folds or lugs. Smaller clamps have two lugs; larger clamps have three. Attachment is accomplished by squeezing the parallel sides of the lugs together to decrease clamp diameter. Made from various ferrous and nonferrous metals, clamps are available in 20 sizes ranging from ¼ to 2⅝ in. ID. Larger sizes can be produced. Made by **Circle Clamp Corp.,** 39 Broadway, New York 6, N. Y.

For more data circle MD-86, Page 221

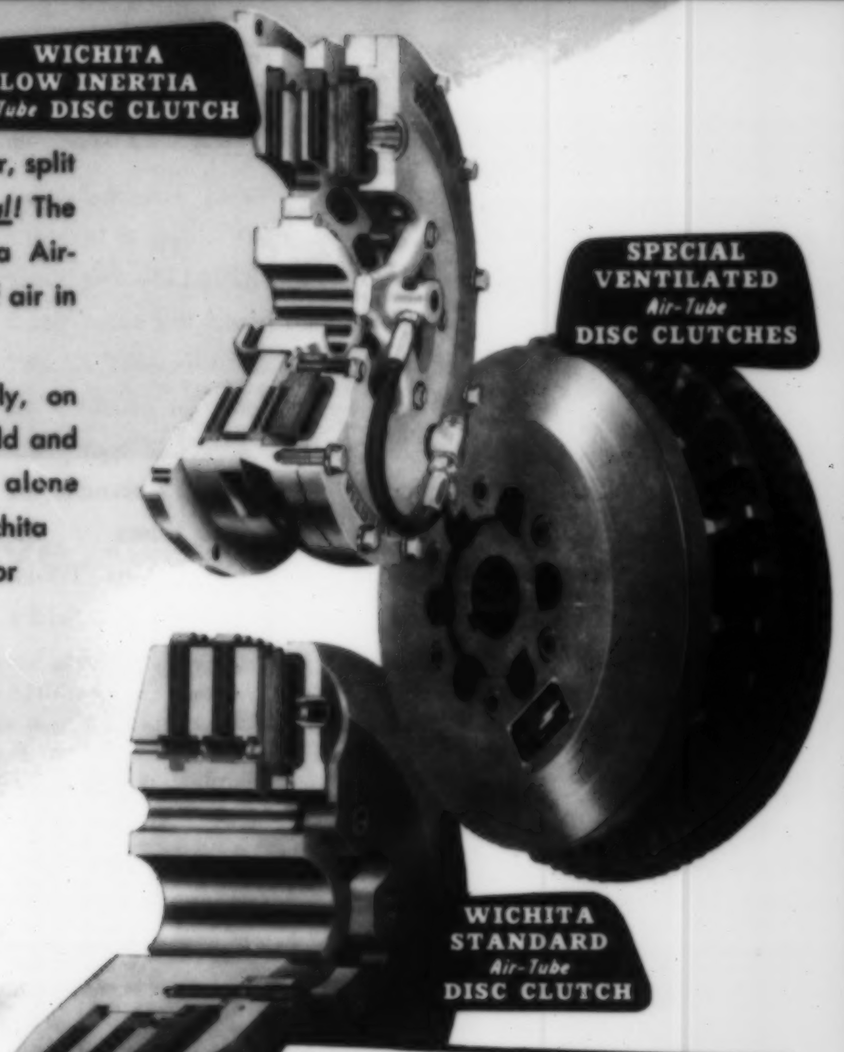
Electric Counter

Super-Wizard electric counter is rated at 1000 counts per minute and will operate at speeds to 1600 counts per minute when suitably actuated. Current draw of less than 5 w permits dependable operation in the plate circuit of electronic tubes having an output of

WICHITA 24" *Air-Tube* Clutches Disengage in

1/27 of a second

SMALLER CLUTCHES EVEN FASTER!



For complete safety of the operator, split second disengagement is absolutely *essential!* The amazing disengagement speed of Wichita Air-Tube Clutches is due to minimum volume of air in tube and to Wichita Quick Release Valves.

Wichita Clutches are operated successfully, on many types of equipment, all over the world and NOT ONE HAS BEEN REMOVED. This alone proves the superior performance of Wichita Clutches. Test a Wichita . . . you'll see for yourself!

Other Major Features

- Soft, Smooth Engagement
- Simple Design
- 3 types of clutches: Standard, Low Inertia, Special Ventilated
- Efficiency Engineered
- Positively Ventilated for Cooler Operation
- Extremely Long Life
- Easier Maintenance

Consult your nearest Wichita Engineer for complete and detailed information.

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-Lohner, Inc., Detroit, Michigan
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—Check with

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IF you use gears in the product you make, we believe it will pay you, as it has others, to become acquainted with FAIRFIELD—the place where fine gears are produced to meet your specifications EFFICIENTLY, ECONOMICALLY! Fairfield's production facilities are unexcelled for making all kinds of accurate, automotive type gears such as are now finding wide use in all branches of industry: for Tractors, Trucks, and Buses . . . for Agricultural Implements . . . for Machine Tools. Ask for latest literature describing Fairfield's facilities. *Your inquiry will receive prompt attention.*

Fine Gears Made to Order

SPUR GEARS—Straight, helical, and internal. Sizes from 16 pitch, 1½" dia., to 1½ pitch, 36" dia.

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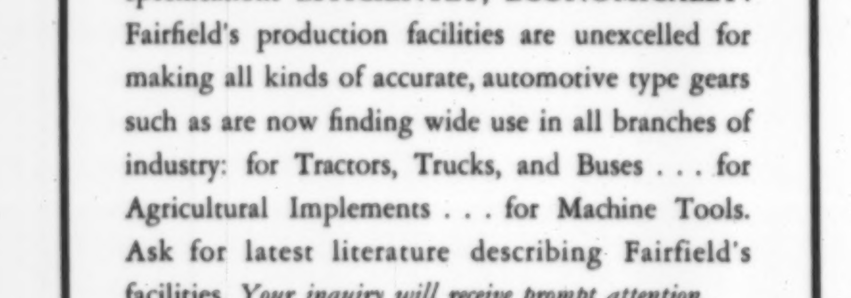
ZEROL—Sizes from 16 pitch, 1½" dia., to 1½ pitch, 21" dia.

WORMS AND WORM GEARS—Worms to 7" dia. Worm gears to 36" dia.

SPLINED SHAFTS—Lengths to 52". Diameters from 1" to 6".

DIFFERENTIALS—10,000 to 300,000 inch pounds capacity.

Note: All of the sizes above are approximate.



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5 w or more. Balanced armature prevents error ordinarily caused by shock or vibration. Counter is available for base or panel mounting and for ac or dc to 230 v in

SUPER-WIZARD

four and six-digit models with knob or key reset. Average life expectancy is 300 million counts. Made by **Production Instrument Co.**, 702-08 W. Jackson Blvd., Chicago 6, Ill.

For more data circle MD-87, Page 221

Automatic Control

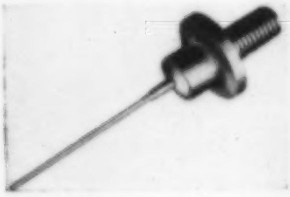
Versatrol control detects minute changes of current or voltage while indicating their magnitude; it trips relays for control as a result of these changes. Containing no vacuum tubes, the device has a signal input section and a section which controls the power. Contact is made directly in the sensitive meter-relay. Signal input can be microamperes or millivolts, ac or dc. Control sensitivity can range from 0.2-ma to 1000 amp or more; voltage sensitivities, from 0.1-mv to over 500 v. Meter-relay can have contacts on the high side and/or the low side. Contact setting is adjustable to any point on the scale. Contacts also can be preset and nonadjustable. Locking coil assures long contact life and positive operation even with con-

siderable vibration or shock. Power relay is rated 5 amp, 115 v, ac noninductive, single-pole, double-throw. Panelmount and U-Mount-It styles are available for custom installations. Made by **Assembly Products Inc.,** Chesterland, O.

For more data circle MD-88, Page 221

Silicon Rectifier

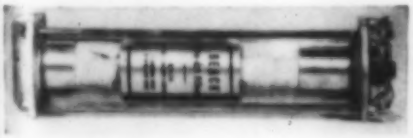
Capable of continuous operation at full power at an ambient temperature of 125 C, group of silicon power rectifiers is applicable to both magnetic amplifier and power supply uses. They have high forward conductance and low current leakage, with reported operating efficiencies of 98 per cent. Rectifier is designed for conduction cooling. Made by **Transitron Electronic Corp.,** Melrose 76, Mass.



For more data circle MD-89, Page 221

Moisture Separator

Model 65 C compressed air moisture separator is designed for use on compressed air lines up to 250 psi. Separator is 2½ in. in diameter by 12 in. long and has ¼-in. thick, clear plastic cylinder walls which withstand pressures in excess of 600 psi. Approximate cleaning capacity of the two silk encased filters in the separator is 1 million cu ft. Intake and outlet connections are for ¼-in. pipe. Transparent cylinder shows when the filter elements should be replaced or when the moisture should be drained from the bottom of the separator. It is rec-



(*Continued on Page 250*)

Eye

Each year more and more companies use super-slow-motion movies (up to 3200 pictures a second) to solve design, production, and maintenance problems involving motion too fast for the human eye to follow. Some even use such movies as a sales tool.

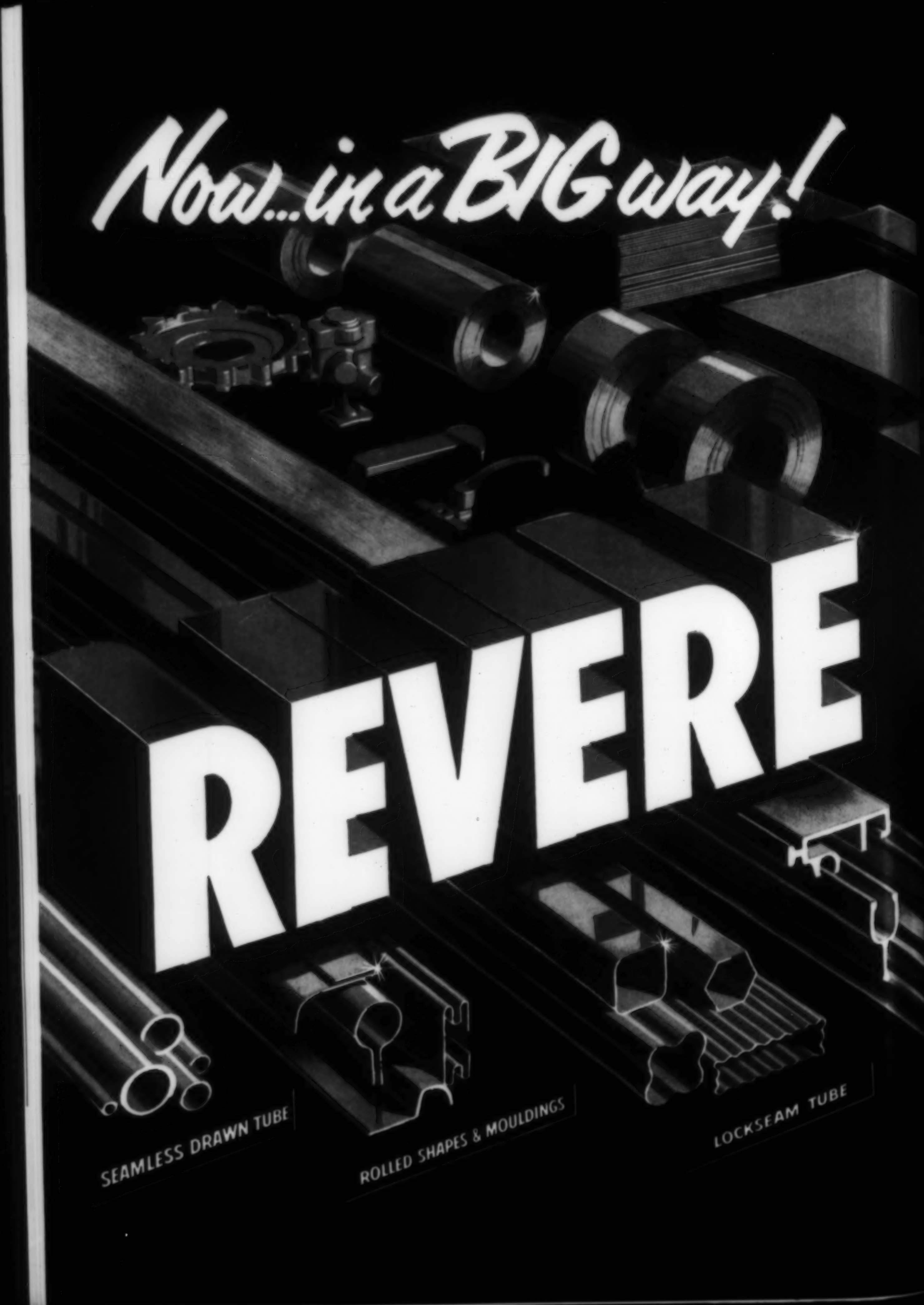
Kodak has just introduced a new film for this work, far more sensitive than any hitherto available. It is already contributing heavily to the achievements of specialists in the use of high speed movie cameras.

But there is one high speed camera on the market so simple that a man can use it successfully without taking time out to become a specialist. It is called, simply, the Kodak High Speed Camera. For full details about it, write *Graphic Reproduction Division*...

EASTMAN KODAK COMPANY, Rochester 4, N. Y.

the Kodak
***HIGH SPEED* Camera**

Kodak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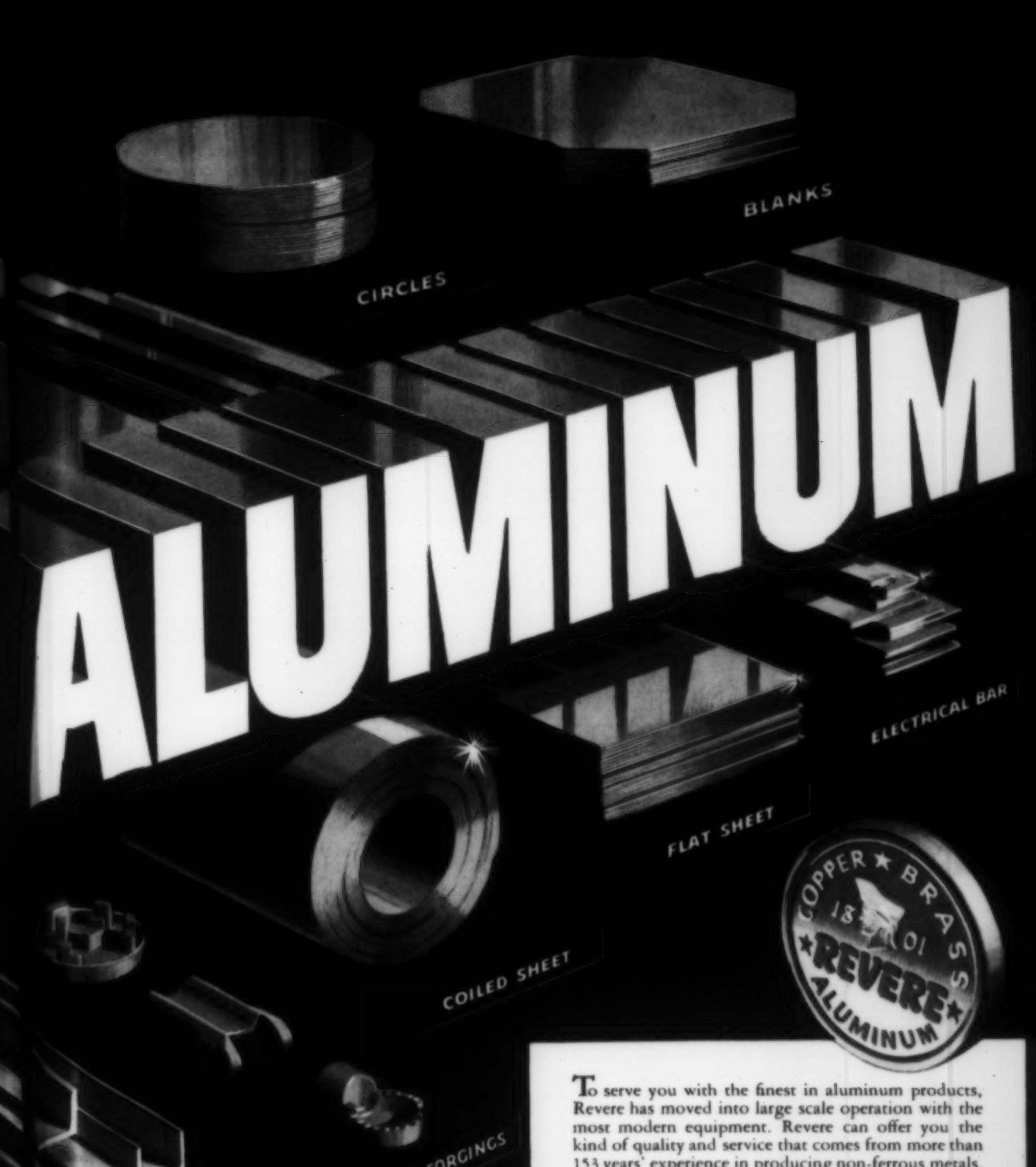
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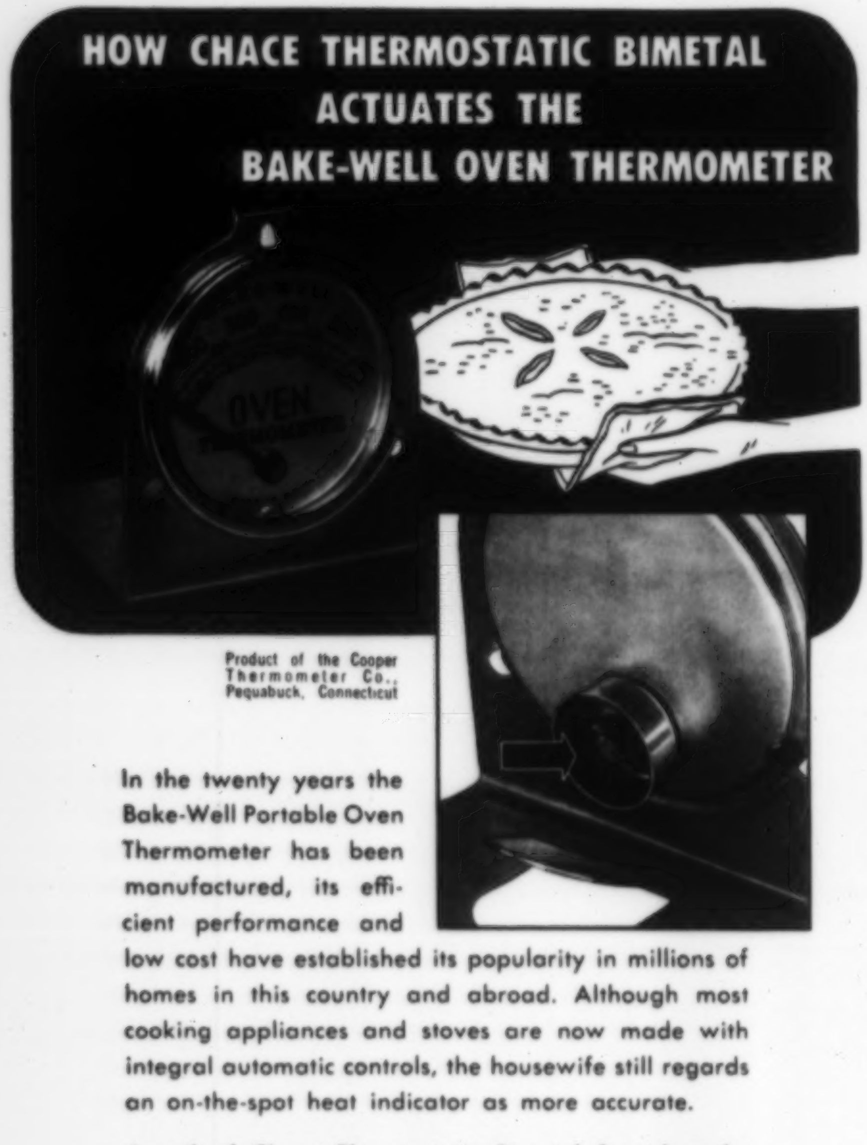


HOW CHACE THERMOSTATIC BIMETAL
ACTUATES THE
BAKE-WELL OVEN THERMOMETER

Product of the Cooper Thermometer Co., Pequabuck, Connecticut

In the twenty years the Bake-Well Portable Oven Thermometer has been manufactured, its efficient performance and low cost have established its popularity in millions of homes in this country and abroad. Although most cooking appliances and stoves are now made with integral automatic controls, the housewife still regards an on-the-spot heat indicator as more accurate.

A coil of Chace Thermostatic Bimetal furnishes the thermally responsive element which actuates this simple device. One end of the coil is anchored to the frame of the thermometer. The other end of the coil is fastened to a pointer. Temperatures in excess of 100°F. cause the bimetal coil to expand, rotating the pointer to register the correct temperature on dial. The Chace Thermostatic Bimetal coil is accurately calibrated at the factory to insure positive temperature indication over many years of dependable service.

Chace Thermostatic Bimetal is available in 29 different types, in strip, coils or in completely fabricated assemblies made to customer specifications. Send now for our new, free 36-page booklet, "Successful Applications of Chace Thermostatic Bimetal," containing valuable engineering information for designers of thermally responsive devices.

IT BENDS WITH THE HEAT
W. M. CHACE CO.
Thermostatic Bimetal
1616 BEARD AVE., DETROIT 9, MICH.

New Parts

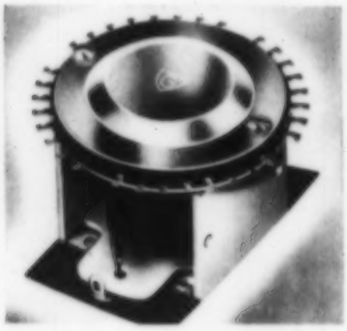
(*Continued from Page 247*)

ommended for use where a high degree of air cleanliness and dryness is required. Made by **Beach Precision Parts Co.,** 120 Mechanic St., Boonton, N. J.

For more data circle MD-90, Page 221

Direct Current Relay

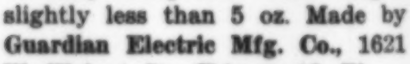
Originally designed as a "group" relay, 32-pole series 805 dc relay is capable of connecting together 32 electrical circuits simultaneously. Individual contact blades are molded in thermosetting phenolic for strength and heat resistance. All contacting members are enclosed in aluminum cover, making relay virtually dustproof. Unit weighs slightly less than 5 oz. Made by **Guardian Electric Mfg. Co.,** 1621 W. Walnut St., Chicago 12, Ill.



For more data circle MD-91, Page 221

Panel Meters

Available for horizontal mounting, as shown, or for vertical mounting, model 1145 side indicator panel meters require a panel area of only 5.5 sq in. Overall dimensions are 3.5 x 1.3 x 3.5 in. deep, plus terminal length as required. Initial accuracy of indicators is ±2 per cent of full scale deflection on dc and ±5 per cent on ac. Microammeter, milliammeter and ammeter ranges are avail-



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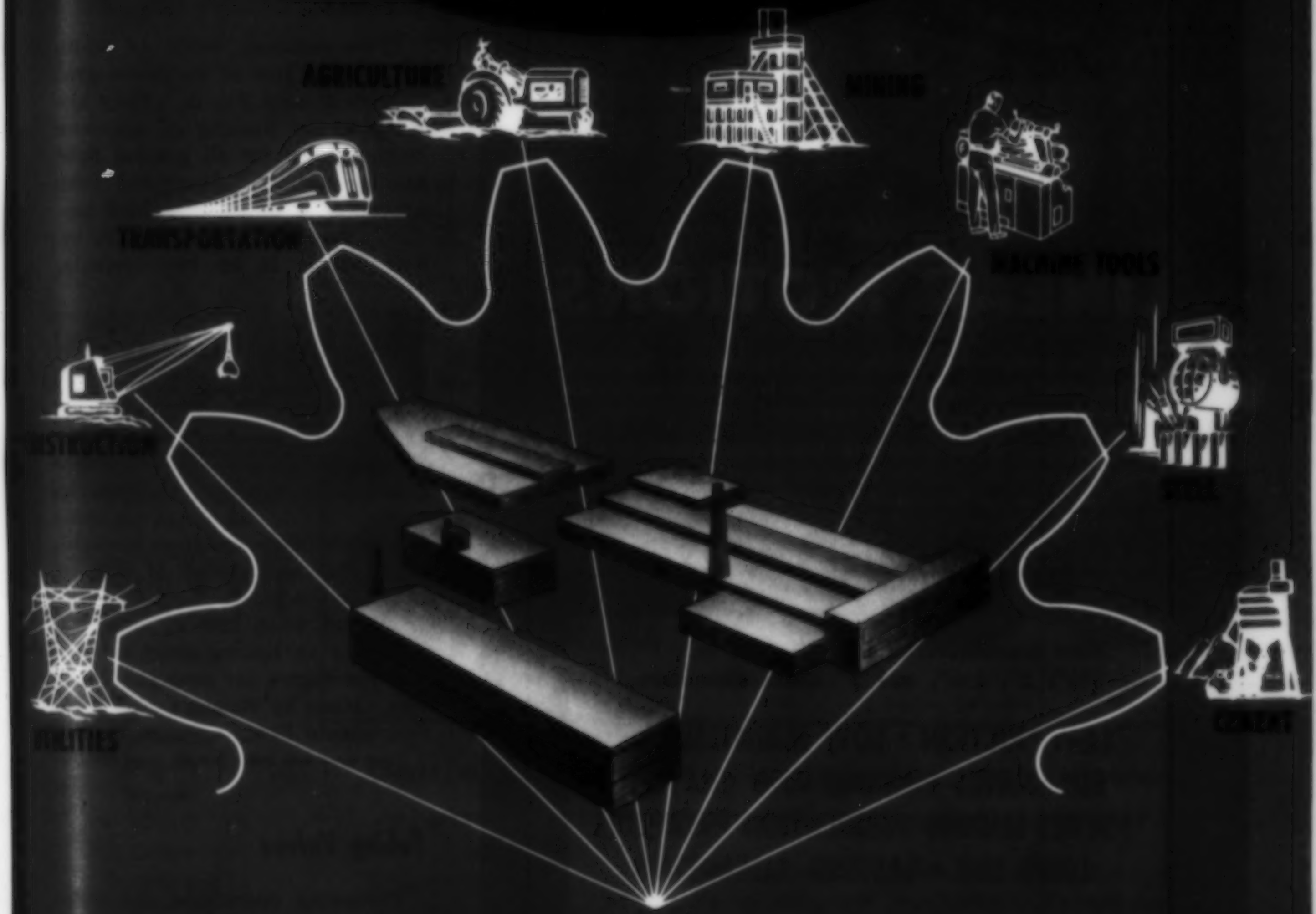
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Look for this mark (ILLINOIS) *the symbol on finer gears*

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Gears for Every Purpose **... one gear or 10,000 or more**

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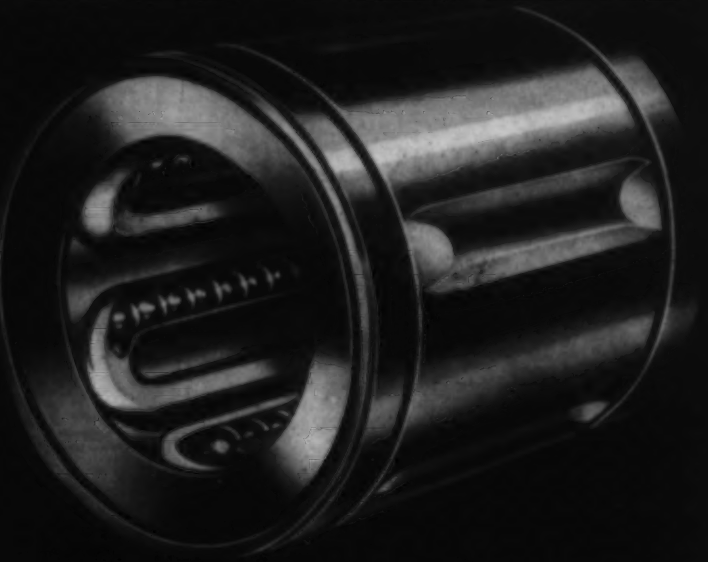
BALL BUSHING



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LINEAR MOTIONS

Sliding linear motions are nearly always troublesome. Thousands of progressive engineers have solved this problem by application of the Precision Series A or Low-Cost Series B BALL BUSHINGS.

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Improve your product. Up-date your design and performance with BALL BUSHINGS!

Now manufactured for ¼", ½", ¾", 1", 1½", 2", 2½", and 3" shaft diameters.

LOW FRICTION • LOW MAINTENANCE
ELIMINATES BINDING AND CHATTER
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Progressive Manufacturers Use Ball Bushings —A Major Improvement at a Minor Cost

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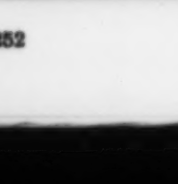
Write for descriptive literature and the name of our representative in your city.



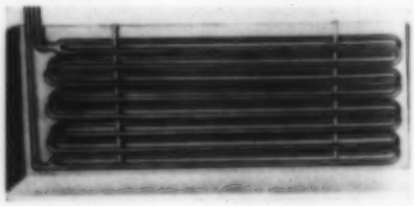
Also manufacturers of NYLINED Bearings — DuPont NYLON within a metal sleeve—for rotation and reciprocation.

able from 50 ua dc; ac voltmeter ranges from 25 to 500 v; dc from 50 mv to 500 v. All meters are self-contained in dustproof plastic cases. Clear plastic front cover is curved to admit light from all directions. Magnetically shielded, the instruments can be installed on magnetic panels up to ¼-in. thick without recalibration. Made by **International Instruments Inc.**, New Haven 15, Conn.

For more data circle MD-92, Page 221

Grid Heaters

Cross-sectional width of units in standard line of Hi-Therm grid heaters is only 2¾ in. They are designed for heating of solutions in tanks and for all general fluid heating service. Staggered tube arrangement accelerates fluid motion. Standard height is 31½ in. and length is to requirements.

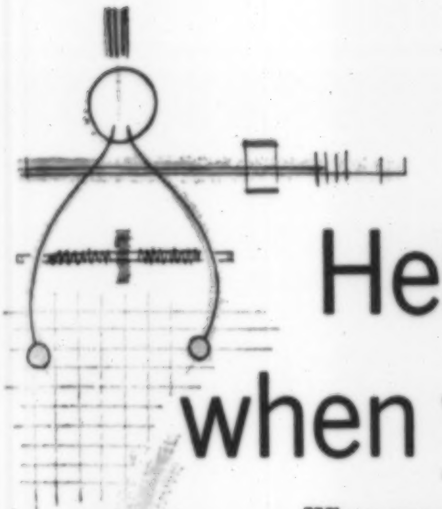


Tubes are fabricated from wrought steel pipe and tested at 350 lb pressure. Average heat transfer coefficient when heating solutions of water to boiling point is 800 Btu per degree per hour per lineal foot. Made by **Rempe Co.**, 360 N. Sacramento Blvd., Chicago 12, Ill.

For more data circle MD-93, Page 221

Tubing Valves

Threading operations are eliminated in the installation of Tube-Line valves, designed for use on tubing. Valve body is type 304 stainless steel; valve stem is heat treated type 410 stainless steel with a rolled thread. Installation is by cutting tubing to desired



Help that counts when you need it most...

When you need help with any power-drive problem, you need it *now.* You get this timely help—and more—from Emerson-Electric ... Here, ready to serve you at a moment's notice, is a group of power-drive specialists who know motors AND the needs of appliance and equipment manufacturers. These men can give you the benefits of 64 years' accumulated experience, beginning in 1891, with the first motor for a sewing machine, and covering hundreds of appliance and equipment applications.

Emerson-Electric specialists are ready to serve you when you need their help. They are always on call. You don't have to wait until they "get around to it." They will start with your design ideas and follow through to final test and application runs.

Profit by Emerson-Electric's years of experience and the combined ability of its motor specialists. They know motors AND the appliance-equipment business.

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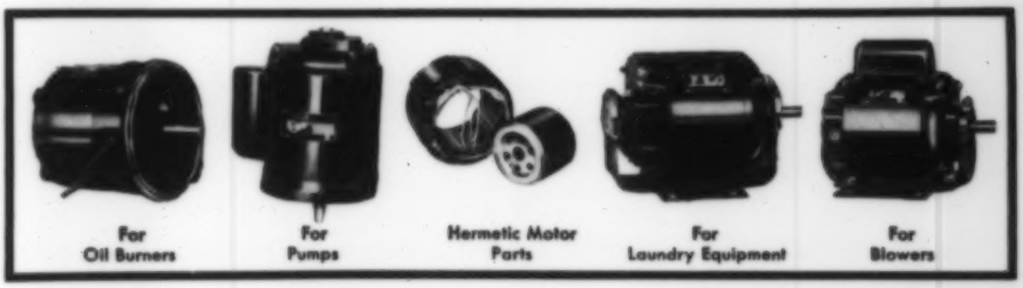

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Call on Emerson-Electric for horsepower you can translate into sales power!

Or, write THE EMERSON ELECTRIC MFG. CO., ST. LOUIS 21, MO., for Bulletins listed below

☐ M 4002-A Capacitor-Start
☐ M 4002-B Split-Phase
☐ M-4002-C Integral
☐ M 4002-D Fan Duty
☐ M 4002-E Oil Burner
☐ M 4002-F Jet Pump
☐ M 4002-G Blower

Emerson-Electric

of St. Louis • Since 1890

exclusive
REULAND
"*Xpandable*" *design*

typical adaptations from this BASIC DESIGN

combines motors • brakes fluid couplings • gear-reducers into tailor-made single-unit POWER PACKAGES!

Motor with Reuland "Through Shaft" magnetic brake

Motor with internal fluid coupling

Motor with fluid coupling and brake on output shaft

Motor with fluid coupling and helical gear reducer

Motor with fluid coupling, output shaft brake and helical gear reducer (second brake may also be added)

Motor with fluid coupling, right-angle worm reducer and brake

GREATER COMPACTNESS...
one service responsibility!

Instead of buying and aligning several separate units, install Reuland *tailor-made, single-unit Power Packages*. You save space and weight, reduce prices up to 25%—simplify installation—improve in-the-field performance.

Literally dozens of combinations are available to fit every powering job. All economical, *standard assemblies* using the basic Reuland "XPANDABLE" motor design.

If your equipment utilizes a motor, brake, fluid coupling, gear reducer (or any combination) why not find out first-hand what a Reuland Power Package can do for you. Give us the details and we'll even submit a "tailor-made" test unit on approval.

OVER 800 "SPECIAL" ELECTRIC MOTOR DESIGNS...

Still further versatility is provided by the Reuland "Library of Specials." Over 800 motors with special electrical and mechanical characteristics...800 ways you can save development work, get in production faster!

Write today, outlining your particular power problem. No obligation, of course.

REULAND ELECTRIC COMPANY
Distributors in all principal cities

WESTERN DIVISION: Alhambra, California • EASTERN DIVISION: Howell, Michigan

length, filing off burrs and slipping on an adapter nut and sleeve. Connecting creates a gas-tight seal which will hold pressures up to 4000 psi. Valves are stocked for ⅛-in. OD by 1/16-in. ID, ¼-in. OD by ⅛-in. ID, ⅜-in. OD by ¼-in. ID and ½-in. OD by ⅜-in. ID tubing sizes. Made by **Autoclave Engineers Inc.**, 832 E. Nineteenth St., Erie, Pa.

For more data circle MD-94, Page 221

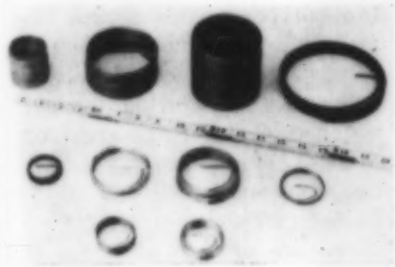
Small Motors

Redesigned line of fractional-horsepower, single-phase motors are rated ¼-hp and smaller. Capacitor-start and split-phase motors have shallower endplates to reduce their length. Ventilating openings are located below centerline. Sleeve bearing motors are lubricated by means of felt packing, cut to specified shapes and inserted in bearing housings with inner and outer seals. This type of construction prevents oil leakage and assures a constant supply of oil to the bearings. Quick-break switch and thermal overload protector are attached to the terminal board, which is mounted inside the stator frame, thus eliminating all internal connections to the endplates. Motors are available with either sleeve or ball bearings and rigid or resilient bases. Made by **Wagner Electric Corp.**, 6400 Plymouth Ave., St. Louis 14, Mo.

For more data circle MD-95, Page 221

Wire Thread Inserts

Wire thread inserts of extra large pitch diameter and wire size provide strong, permanent threads in soft materials such as aluminum, magnesium, plastic and wood, as well as in iron and steel. Standard stock sizes range from



4-40 to 1½-12; special large inserts have been formed up to 6 11/16-in. diameter with 12 threads per inch. Large diameter inserts can be formed of wire from 3/16 down to 0.015-in. diameter. Inserts shown are all NC, NF or pipe threads; however, inserts of large pitch diameter can be formed in other thread series. They can be formed for left-hand threads, as well as for double, triple or quadruple lead threads. Tolerances are held to 0.0002-in., and surface finishes from 8-15 mu in. are possible. Hardness up to Rockwell 50C can be obtained in 18-8 stainless steel, the standard material used. Inserts also can be phosphor bronze, Hastelloy C, music wire and other metals. Made by **Heli-Coil Corp.**, Shelter Rock Rd., Danbury, Conn.

For more data circle MD-96, Page 221

Time Delay Relay

Type A Silic-O-Netic time delay relay is available with standard time delays from ¼ to 120 seconds. Movable iron core, sealed in nonmagnetic metal tube extending through a solenoid coil, is drawn into magnetic field resulting when coil is energized. Silicone fluid slows rate of core travel, controlling the response time. Magnetomotive force has been increased over that of earlier relays. This fac-

More And More Manufacturers Are Installing

MARVEL SYNCLINAL FILTERS

AS STANDARD EQUIPMENT

Manufacturers of hydraulically actuated equipment and others with low pressure liquid circulating systems demand their equipment to perform consistently with all the productive efficiency they build into the machine that bears their name. Since these systems must be kept free of damaging particles, the selection cf a filter is an important factor. Here are some of the outstanding reasons for the increasing preference for Marvel Synclinal Filters to do this all-important job!

BECAUSE . . . Marvels are designed to give maximum ACTIVE filtering area rather than total filtering area. Only ACTIVE FILTERING AREA COUNTS!

BECAUSE . . . Marvels greater storage space for filtered out particles allows longer periods of "production" time at absolute minimum in maintenance cost and "down-time."

BECAUSE . . . Marvels can be disassembled, cleaned and reassembled by any workman in a matter of minutes. Line type operates in any position and may be serviced without disturbing pipe connection.

BECAUSE . . . Marvels are protected and of sound construction to give long life and efficient filtration. They meet J. I. C. Standards.

BECAUSE . . . Marvels (Both Sump and Line Type) are available in individual capacities from 5 to 100 G.P.M. and choice of mesh sizes ranging from coarse 30 to very fine 200, they get a filter to fit their specific requirements.

BECAUSE . . . Marvel not only delivers a top grade filter in both quality and performance, but delivers IMMEDIATELY—shipments are made the same day orders are recieved, if desired.

SUMP TYPE
(Cutaway)

LINE TYPE
(Cutaway)

FACTS — NOT CLAIMS

Engineers decide on the basis of the record, on the basis of measurable facts rather than claims of the "campaign promise" variety. Here is a fact with meaning.

➡ OVER 550 MANUFACTURERS MAKE MARVEL SYNCLINAL FILTERS THEIR O.E.M. CHOICE

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Amphitheatre
CHICAGO, ILLINOIS
May 16-20, 1955

For Dependable Protection on All Hydraulic and Low Pressure Systems Investigate

MARVEL SYNCLINAL FILTERS

WATER FILTERS
Both sump and line type filters have been adapted for use in all water filtering applications. No changes have been made in the basic, balanced synclinal design.

FILTERS FOR NON-FLAMMABLE HYDRAULIC FLUIDS
Marvels most recent development is a filter for the efficient filtration of all types of non-flammable hydraulic fluids.

Catalogs containing complete data available on request

MARVEL ENGINEERING CO.
625 W. Jackson Blvd.,
Chicago 6, Ill.
Phones—Franklin 2-3530
and Franklin 2-4431

MD-4

Without obligation, please send me complete data on Marvel Synclinal Filters, as follows:—
☐ Catalog # 106—For Hydraulic Oils, Coolants and Lubricants
☐ Catalog # 300—For WATER
☐ Data on filters for Non-flammable hydraulic fluids.

Name ______
Title ______
Company ______
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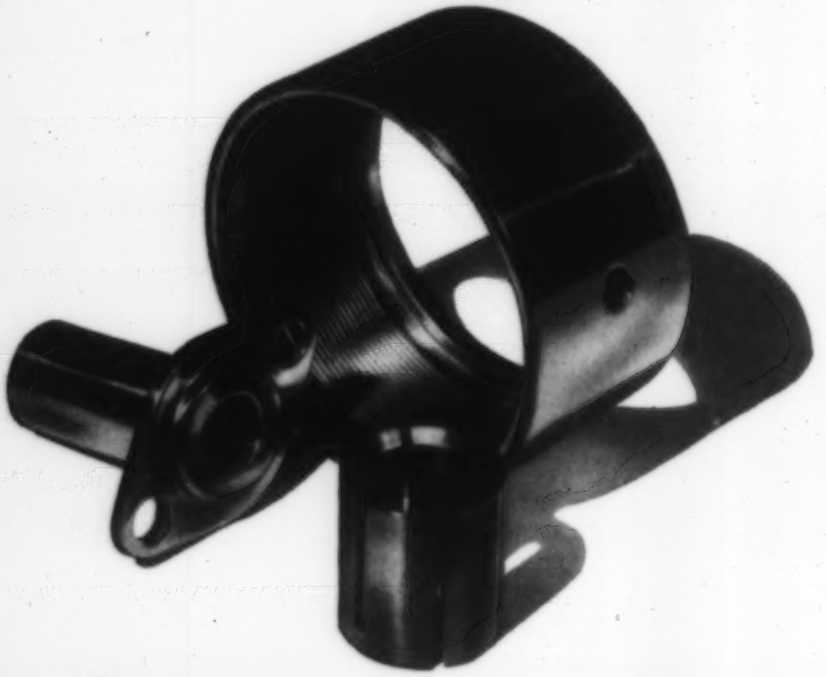
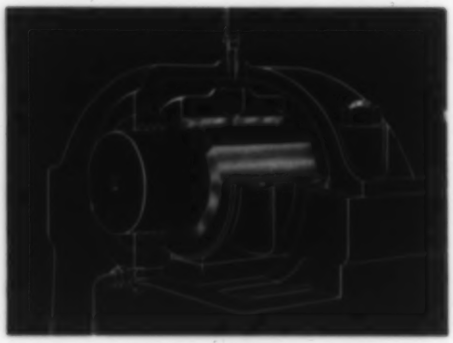
BEARING THAT...
meets many needs



Cast Bronze Bunting Bearings can be supplied in many forms from the simplest to the most intricate. They offer many ways to cut the cost of both design and production without any sacrifice of performance or durability.

It may save you much expense and trouble to find out what Bunting Bronze Bearings can do for you. There is a Bunting engineer near you for consultation. Or write our Product Engineering Department at Toledo.

The Bunting Bearing offers ways to reduce the cost of a design and to employ designs that provide more economical production as well as lower initial cost.



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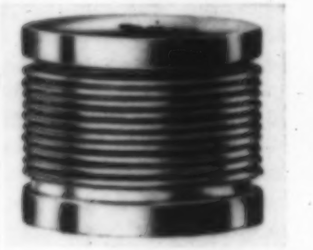
tor, combined with spring loading of armature, achieves high speed contact action with substantial pressure for reducing contact resistance. Coil ratings are from 24 to 240 v ac and 6 to 125 v dc. Made by **Heinemann Electric Co.**, 572 Plum St., Trenton 2, N. J.

For more data circle MD-97, Page 221

Metal Bellows

High temperature resistant, noncorrosive and nonmagnetic characteristics of Monel are incorporated in this line of bellows for use in electrical and electronic equipment where stray magnetic fields are a problem. Made of 326 Monel, bellows are applicable in tunable cavity uses such as magnetrons and vacuum variable capacitors. Wide range of sizes is available from **Clifford Mfg. Co.**, 124 Grove St., Waltham 54, Mass.



For more data circle MD-98, Page 221

Pillow Blocks

Improved SP line of pillow blocks and flanges have increased bearing capacity, greater alignment range and better interchangeability. Other design changes have been made in reinforcement of housing, shaft lock and dustproof seals. These light-

A complete line of POWERGRIP "TIMING" Belts by U.S. Rubber

U.S. PowerGrip TIMING Belt with its positive engagement takes hold of the pulley grooves with perfect fit, perfect grip. Slippage or power loss can't happen.

FAST DELIVERY
COMPLETE ENGINEERING SERVICE
FULL STOCKS

As an industrial designer, you have often met problems involving the transmission of mechanical power: hand tools, lathes, drill presses, saws, electric typewriters are some examples. In such cases, you had to go along with the limitations imposed by V-belts, chain drives or gears. But now the U. S. PowerGrip TIMING® Belt, developed and perfected and thoroughly proved for over six years by United States Rubber Company, gives you entirely new freedom, new scope, new horizons of design. MOREOVER, the "U. S." network of distribution centers, sales offices and TIMING Belt Distributors permits fast supply plus complete engineering service.

EVER WISH YOU COULD USE SMALLER PULLEYS? You can with the U. S. PowerGrip TIMING Belt... *no slippage, no take-up*. This permits very short centers and high ratios. Light weight of PowerGrip permits high speeds.

DO LUBRICATING AND HOUSING DEVICES GET IN YOUR WAY? The absence of metal-to-metal contact in the U.S. PowerGrip TIMING Belt makes lubricants and oil-retaining housings unnecessary. Less cost, less weight.

DO HIGH BELT SPEEDS SLOW YOU DOWN? The U. S. TIMING Belt can easily handle speeds up to 16,000 F.P.M. Light weight keeps centrifugal force way down. Yet, because it cannot slip, U. S. PowerGrip TIMING Belt can be operated at speeds so slow as to be imperceptible.

WHAT ABOUT HORSEPOWER? H.P. Range is 1/100 to 300 or more. Stock drives run to 50 H.P., but wider belts and pulleys can be made on order in standard lengths and diameters.

IS EFFICIENCY ALL IT COULD BE? Because there are no friction-creating joints, no slippage loss, no lubricated drag—minimum heat generation and minimum bearing loads, U. S. PowerGrip TIMING Belts have an efficiency of close to 100%.

Write to any of the 27 District Sales Offices or the address below. Ask for free catalog.

"U. S." Research perfects it... "U. S." Production builds it... U. S. Industry depends on it

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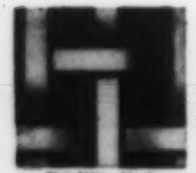
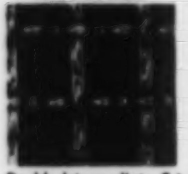
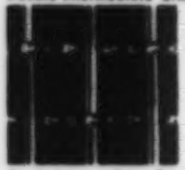
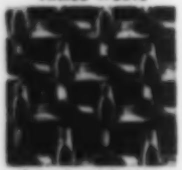

Flat Wire Mesh

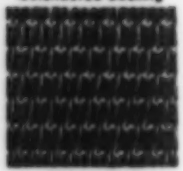

Double Intermediate Crimp


Single Intermediate Crimp

Double Crimped

Twilled Weave


Calendered Backing


Oblong Mesh

Plain Dutch Filter

Twilled Dutch Filter

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INDUSTRIAL WIRE CLOTH

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COMPLETE LINE—Cambridge stocks include a wide variety of specifications from the finest to the coarsest mesh in any metal or alloy.

QUALITY—Accurate mesh count and uniform mesh size are assured by individual loom operation and careful inspection just before shipment.

PROMPT SERVICE—You get immediate delivery on the most frequently used types of cloth. If your needs are not in stock, we'll schedule our looms to get your material to you without delay.

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LET US QUOTE *on your next order for wire cloth. Call your Cambridge Field Engineer—he's listed under "Wire Cloth" in your classified telephone book.*

OR, WRITE DIRECT for FREE 80-page CATALOG and stock list giving full range of wire cloth available. Describes fabrication facilities and gives useful metallurgical data.

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Maryland

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medium service units are for shaft diameters of ¾ to 2 15/16 in. Made by **Ahlberg Bearing Co.**, 3025 W. 47th St., Chicago 32, Ill.

For more data circle MD-99, Page 221

Self-Locking Fastener

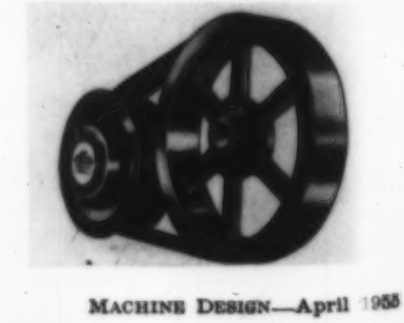
Banc-Lok T 76 self-locking fastener is easily installed in a hole of correct size by pushing in with the fingers, then locking by spreading with a punch. It may also be locked in soft materials by means of a tapered point screw. Design permits use of a free-running screw, such as knurled thumbscrew. Fastener grip length

will accommodate soft aluminum extrusions in thicknesses of 0.045 to 0.085-in. Application can be made to such other metals as cold rolled steel, hard aluminum and brass. Grip length then becomes critical with about 0.005 to 0.010-in. tolerance. Made by **Boots Aircraft Nut Corp.**, Banc-Lok Div., Newtown Turnpike, Norwalk, Conn.

For more data circle MD-100, Page 221

Variable Speed Drive

Infinitely variable speed over a 2 to 1 speed ratio is provided by this small variable speed drive for 1 to 5-hp loads. Both flanges are moved simultaneously by a single adjusting screw to change pitch



Major advance in Low Pressure SOLENOID VALVES

Extra heavy industrial type construction with tight seating assured
—for manufactured
and natural gas,
air, propane, butane,
water, gasoline
and light fuel oil
—to 180°F.

Mount this new ASCO Low Pressure Solenoid Valve in *any* position without affecting its operation. For pressures up to 7 Psi, the Bulletin 8030A helps give full design flexibility to gas pilot applications on industrial ovens and furnaces — automatic dispensing and vacuum holding applications.

And ASCO combines ruggedness with simplicity by housing a single moving element — the stainless steel core and composition disc — in an extra heavy forged brass body.

Operation is just as remarkable. Energizing the solenoid with only 10 watts provides positive opening action. Both ⅜″ and ½″ pipe sizes feature oversized ports (⅜″ orifice) for greater flow at an exceptionally low pressure drop.

There's *one* source that solves virtually any solenoid valve problem—ASCO. For full data on this new Low Pressure Solenoid Valve, write today for Application and Development Report 8030A.

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Automatic Transfer Switches
Electromagnetic Controls
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NEW NP
Power Drive Cylinder
. . . has all the "most wanted" design features

No other cylinder offers you so many vital features: compact, streamlined design; lightweight aluminum alloy and steel construction exceeds all strength requirements; interchangeable mountings — foot, flange, pivot, clevis and trunnion. Every cylinder can *operate with air, water or oil without interchanging or adding parts:* Adjustable cushioning (optional) can be added to any cylinder at any time.

PLUS

1. Sealed-in lubrication eliminates line lubricators.
2. Rod wiper and long, self-lubricating bronze rod bearing.
3. Self-compensating synthetic multiple "V" rod packing.
4. Rod packing and bearing externally removable.
5. Large porting gives quick response and smooth performance.
6. Rotatable end caps allow 360° piping location.
7. Rust-proofed cylinder tubing has tough I.D. surface.
8. Bronze piston bearing assures maximum support.
9. Ground and polished stainless steel piston rod.
10. Synthetic "U" cups automatically adjust for wear.

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Designers and manufacturers of mechanical, pneumatic, hydraulic, electric and electronic equipment and systems

diameter. Adjustable flanges are clamped to eliminate fretting corrosion. Designed with a minimum of shaft overhang, the compact unit employs a single, wide range belt. No lubrication is required. Made by **T. B. Wood's Sons Co.**, Chambersburg, Pa.

For more data circle MD-101, Page 221

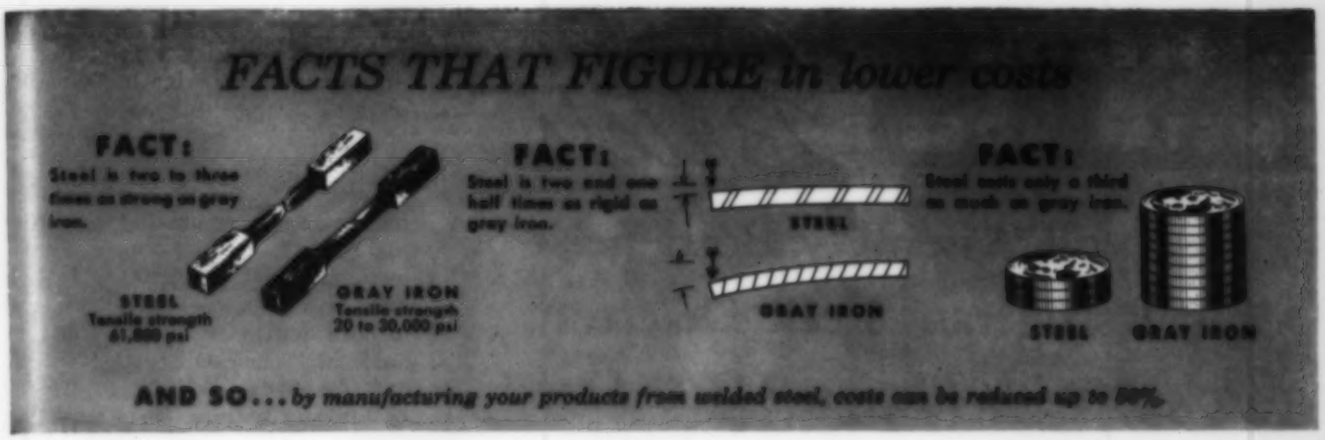
Strain Relief Bushing

Developed for use with the new SPT-3 and HPN No. 18 and No. 16 wires in heavy nonportable appliances such as refrigerators, washers, freezers and circulators, No. SR-5K strain relief bushing is UL-approved. Made of nylon, bushings enhance product appearance and simplify wiring. They are placed over the wire at the desired location, then snapped into the chassis hole. Made by **Heyman Mfg. Co.**, 1200 Michigan Ave., Kenilworth, N. J.

For more data circle MD-102, Page 221

Manual Motor Starter

Snap-action, twin-break silver contacts incorporated in this across-the-line manual motor starter minimize arcing and provide long contact life. Overload protection is also afforded. Intended for use with fractional horsepower motors



FACTS THAT FIGURE in lower costs

FACT: Steel is two to three times as strong as gray iron.

FACT: Steel is two and one half times as rigid as gray iron.

FACT: Steel costs only a third as much as gray iron.

AND SO . . . *by manufacturing your products from welded steel, costs can be reduced up to 50%.*

WELDED DESIGN COSTS 36% LESS

. . . lighter yet more rigid

COST of producing this oversize steady rest for a Boye & Emmes engine lathe has been cut 36% by designing for welded steel construction. New design is stronger, more rigid and easier to mount on the lathe because it is lighter than comparable capacity cast iron rest.

Additional savings of $320.00 resulted by eliminating the need for a pattern. No filling or grinding is necessary. Only work required with new steel design is machining and painting.

Savings like these are possible on many of your products. Have a Lincoln representative analyze your products and show how welded steel can be put to work to simplify production and cut your costs.

WELDED STEEL DESIGN *of 36" maximum capacity steady rest for engine lathe is fabricated from steel plate. Fillet welds are made in fast, down-hand position. Photos courtesy of Boye & Emmes Machine Tool Co., Cincinnati, O.*

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The World's Largest Manufacturer of Arc Welding Equipment

FLEXON METAL HOSE Design Briefs

Cost and Assembly Bottleneck on Refrigerant Leak Detector Broken with Flexon Metal Hose!

This device is used to test for Freon leaks in refrigerating systems. The Flexon Metal Hose is used as a syphon hose to reach inaccessible areas and bring up an air sample. The leak detector analyzes the sample for the presence of Freon which would indicate a leak in the system. The unit is manufactured by Just Rite Manufacturing Co., Chicago.

FLEXON
The Complete Line
for the Designer

REX-WELD corrugated metal hose in steel, bronze and alloys; sizes 3/16" through 24", I.D.; for burst pressures to 12000 psi.

REX-TUBE interlocked, square locked and ball bearing type hose and tubing in steel, bronze, stainless steel and other alloys; sizes 3/16" through 12", I.D. for low and moderate pressures and for use as conduit, ducting, exhaust, protective armor, etc.

DESIGN GUIDE No. 145 gives basic specifications and application data for Flexon Metal Hose. Write for your copy, today.

The designer's problem on this leak detector was to reduce cost and simplify assembly. The answer was found in using steel Flexon Rex-Tube Type RT-13 for the syphon hose. Rex-Tube Type RT-13 is a square locked flexible tubing with heavy asbestos packing. The use of Rex-Tube not only reduced cost and simplified assembly but provided a hose that is able to withstand hard usage better than the previous material.

If you have a design problem involving the conveying of liquids, gases or granular solids, it will pay you to consider Flexon Metal Hose. For specific recommendations, send an outline of your requirements.

Flexonics Corporation
CHICAGO METAL HOSE DIVISION
1339 S. THIRD AVENUE • MAYWOOD, ILLINOIS
FORMERLY CHICAGO METAL HOSE CORPORATION
Manufacturers of flexible metal hose and conduit, expansion joints, metallic bellows and assemblies of these components.
In Canada: Flexonics Corporation of Canada, Ltd., Brampton, Ontario

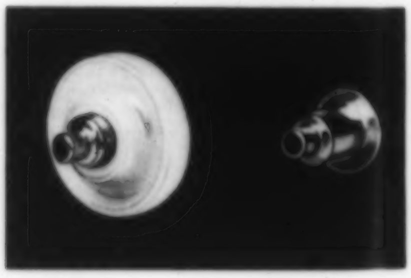
Flexon identifies products of Flexonics Corporation that have served industry for over 53 years.

driving small machine tools, woodworking equipment, fans and blowers, unit is operated by means of an on-off standard toggle lever. Starter has straight-through wiring with permanently identified markings. Eutectic alloy thermal overload relay with inverse time limit is incorporated and is offered in both double and single pole and open and enclosed types. Knockouts for ½-in. conduit are provided top and bottom. Open type has starter mechanism confined in a phenolic shell. It has "break-off" plaster ears and will fit a standard surface or flush type outlet box. Made by **Cutler-Hammer Inc.,** 328 N. Twelfth St., Milwaukee 1, Wis.

For more data circle MD-103, Page 221

Roller Stud

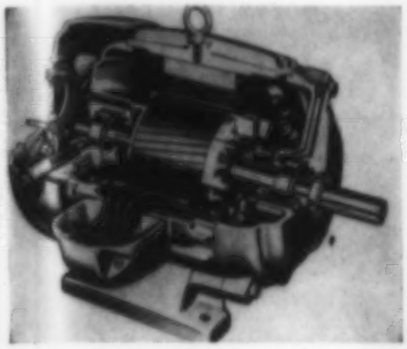
Ample strength at low cost is provided for most applications by this Roll Free drawn steel stud for nylon rollers. Stud is available from stock in four standard sizes, with special sizes made to specifications. Stud has a smooth bearing surface. It can be plated or in clean finish and also can be supplied in brass or stainless steel for applications where corrosion is a factor. Available from **Waterbury Pressed Metal Co.,** 300 Chase Ave., Waterbury 14, Conn.



For more data circle MD-104, Page 221

Totally Enclosed Motor

Conforming to recently adopted NEMA dimensional standards, type J totally-enclosed motors are produced in 1 to 10-hp fan-cooled models and in 1 and 1½-hp fanless types. They are engineered for operation where fumes, dusts and moisture are prevalent. Bearings are accessible without disas-

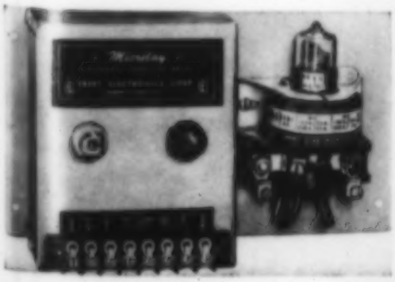


sembly, and external surfaces are cast iron for corrosion resistance. Ribbing adds strength and heat dissipating capacity. Improved slinger seal on shaft adjacent to bearing prevents entrance of moisture. Split-hub ventilating fan is protected by cast iron guard. Lubri-flush system of transverse lubrication permits thorough purging of old grease when desired. Made by **U. S. Electrical Motors Inc.**, P. O. Box 2058, Los Angeles 54, Calif.

For more data circle MD-105, Page 221

Switching Relay

Control of high power-high current loads up to 60 amp or 3 hp from very low current, low power devices or circuits is possible with the Micrelay, an electronically controlled, ac-operated relay. Typical activating devices are photoelectric cells, thermostats and other thermal instruments, meter type contacts and circuits controlled by resistivity of fluids and capacitance of dielectrics. Instrument employs one type 2D21 Thyratron tube and a mercury plunger relay with 35 or 60-amp contact rating at 115 v as required. The UL-approved unit supplies its own operating voltages for high and low impedance applications, suitable for control



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POPE

HEAVY DUTY
WHEEL HEADS
"A"
"B"

Note the big precision bearings and the big shaft. A pair of precision thrust bearings stabilize the shaft against any axial movement in either direction. (No end play)

The double row cylindrical roller bearings carry the radial loads with ease and at low temperature.

Power-Max 25 HP—available with standard No. 30, 40, 50 or 60 milling machine noses.

Send us your specifications and ask for Catalog No. 59

Taper mounting provides for precise individual preloading of the radial bearings.

POPE Heavy Duty Wheel-Head Spindles are designed for a wide variety of applications such as grinding, boring, milling, drilling and many other operations requiring PRECISION COMBINED WITH RUGGEDNESS in the spindles.

For continuous production and trouble-free operation THERE'S NOTHING LIKE A POPE SPINDLE WITH ROLLER BEARINGS.

No. 94

Specify POPE PRECISION SPINDLES

POPE MACHINERY CORPORATION

CHROMALOX
"PACKAGED"
Electric
IMMERSION
HEATERS
WITH BUILT-IN THERMOSTATS

For heating water, oils, tars, greases, plating baths, pickling solutions, etc.

"Packaged" Chromalox Electric Heaters, combining heater and thermostat, are the economical, efficient solution to many heating problems. Uses include: heating tanks, drums and process kettles; melting greases, asphalts and similar viscous fluids; heating degreasing, pickling and plating baths. Available with sheaths of copper or steel, and with lead for use in corrosive solutions. Types, sizes and ratings to meet your needs.

For *all* the facts get CATALOG 50

It gives full data on thousands of time, money, labor-saving Chromalox Units.

A-4443
Industrial Div., EDWIN L. WIEGAND CO.,
7575 Thomas Blvd., Pittsburgh 8, Pa.

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CHROMALOX
ELECTRIC HEAT
FOR MODERN INDUSTRY

circuit impedances from 10 megohms to 100,000 ohms. Operation may also be from an external 9-v ac or 12.5-v dc minimum signal of source impedance up to 10 megohms. Relay may be normally open or closed. Made by **Ebert Electronics Corp.**, 212-26 Jamaica Ave., Queens Village 28, N. Y.

For more data circle MD-106, Page 221

Hydraulic Springs

Shortening of chambers of standard Wales Hydra Springs makes possible new line of semi-standard units with a wider range of applications. Utilizing the compressibility of fluids called Comproils, this line of high capacity springs is reported to provide up to ten times more force in a smaller space than mechanical springs. Illustrated spring is 2⅛ in. long by 1⅜ in. diameter and provides a 700-lb preload and 4000-lb end load at a ⅛-in. stroke. Force and stroke can be adjusted by changing preloads or volumes or types of Comproils. Springs are easily installed, self-contained and dampened and adjusted in place. Make by **Wales-Strippit Corp.**, Hydra Spring Div., 345 Payne Ave., North Tonawanda, N. Y.

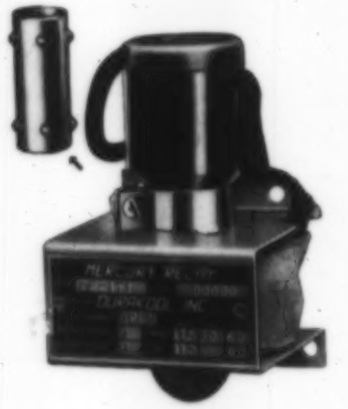
For more data circle MD-107, Page 221

Phosphor Bronzes

Duraflex fine grain phosphor bronzes are reported to possess better fatigue life and formability than conventional phosphor bronzes and at the same time retain equal surface appearance, smoothness and resistance to corrosion. Metal is available in

Stick Free
CORE SHELL
multiplies
mechanical operating life
5 to 6 times

PRE-SET TAMPER PROOF
TIMER-RELAY



A unique one-piece drawn core-shell with embossed guide points increases the mechanical operating life of the Durakool Timer-Relay five to six times, practically putting it in a "fail-safe" class. These relays are available in single or multiple units with single unit capacities of 10, 30 and 60 amperes. Time delays from 0.15 to 20 seconds—any operate-release time combination. These new 1955 relays are now in production—no extra cost.

GUARANTEED FOR AC-DC APPLICATION
and:

- No plunger sticking
- No chatter
- Quiet operation
- No double contacting

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Durakool
ALL-STEEL MERCURY
Timers

FOR THE FIRST TIME...

uniformly perfect "O" Rings
at mass-production costs

Linear, with a new, automatic process, now brings you Roto-Molded "O" Rings—precise, compression-molded quality, at mass production costs!

This high speed, instrument-controlled process is exclusive with Linear. It produces uniformly cured perfect circle rings with flash-free finish, pre-stretched grain structure, and complete freedom from contamination by foreign inclusions.

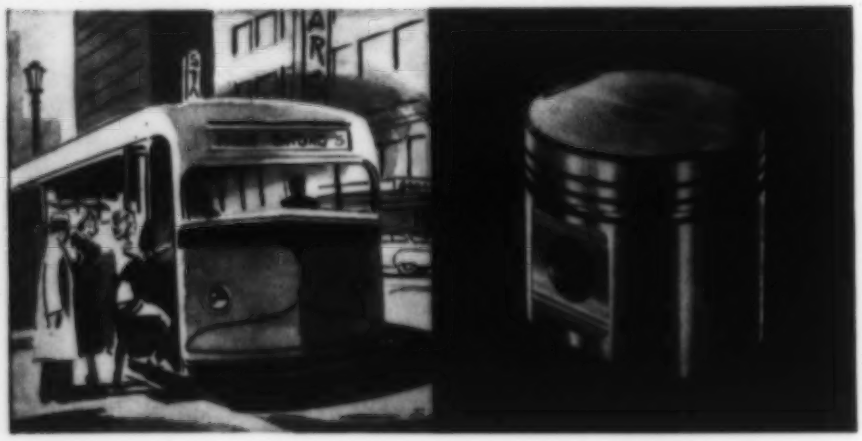
WHY SPECIFY LINEAR ROTO-MOLDED "O" RINGS?

Because they provide greater molded-in strength and wearing properties at a cost comparable to ordinary "O" rings. Moreover, Linear Roto-Molded "O" Rings are dimensionally stable and compounded to *fit the job*.

Linear Roto-Molded "O" Rings are mass produced . . . available for quick delivery in a variety of sizes and materials to meet the exact needs of your application.
Write or call today for full details.

"PERFECTLY ENGINEERED PACKINGS"
LINEAR
LINEAR, Inc., STATE ROAD & LEVICK ST., PHILA. 35, PA.

Garbage Disposers and Buses



Thompson Precision-Engineers Light Metal Castings for All Industry

A HOUSEWIFE using her garbage disposer unit and a bus driver threading his way through traffic have one thing in common—both count on Thompson. The garbage disposer unit and the bus are each improved by precision-engineered castings made by Thompson's versatile Light Metals Division.

The housewife's garbage disposer uses several parts manufactured by Thompson, including the housing—the bus uses several precision-engineered parts, including pistons.

Garbage disposer housings and bus engine pistons are but two of the many light, strong, durable castings designed, developed and manufactured by Thompson for a long list of diversified customer uses. Today Thompson is producing light metal castings for such products as washing machines and jet planes, outboard motors and tractors, automobiles and industrial engines; ice scoops and aircraft engines.

Behind this ability to aid all forms of industry are over 50 years experience in research and manufacture of precision metal parts. Regardless of your product, if you use castings, Thompson's creative engineers will gladly show you where and how you can simplify your operations and save on costs with Thompson Light Metals Castings.

For a detailed description of the Thompson Light Metals facilities which are available to you, send for your free copy of "Creative Castings." Just write to Dept. M-1, Light Metals Division, Thompson Products, Inc., 2269 Ashland Road, Cleveland 3, Ohio.

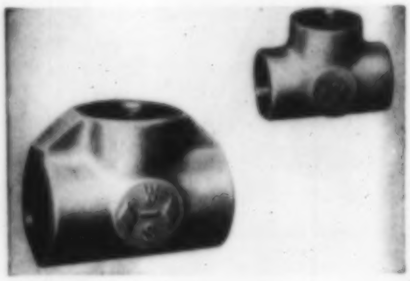
You can count on
Thompson Products
LIGHT METALS DIVISION
2269 Ashland Rd. • Cleveland 3, Ohio

range of tempers listed in ASTM specification B103 and in alloys A, C and D of the specification. Sheet metal in thicknesses up to about 0.062-in. and wire up to about 3/16-in. diameter are offered. The several tempers offered permit wide range of uses. Made by **American Brass Co.**, Waterbury 20, Conn.

For more data circle MD-168, Page 221

Pipe Fittings

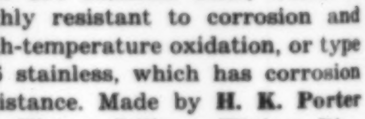
Screw-end and socket-welding types of 150-lb stainless steel pipe fittings are available for standard pressure services. Available in ⅛ to 2-in. sizes, the fittings are either type 304 stainless steel, which is highly resistant to corrosion and high-temperature oxidation, or type 316 stainless, which has corrosion resistance. Made by **H. K. Porter Co.**, Watson-Stillman Fittings Div., 109 Aldene Rd., Roselle, N. J.



For more data circle MD-169, Page 221

Permanent Magnet Motors

Series 1200 P.M. subminiature, permanent-magnet, subfractional motors are particularly adaptable for use in servo systems where low voltage starting conditions must be met. Motors offer up to 5 oz-in. of torque at speeds of 60 to 30,000 rpm and operate on from 3 to 115 v dc. Specially designed

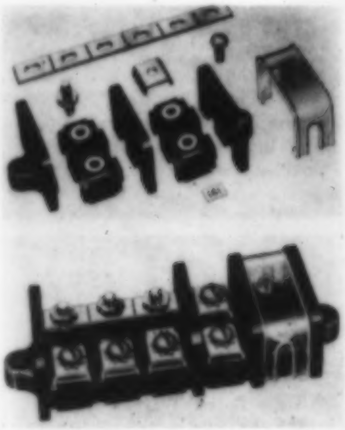


laminated field shoes are used in conjunction with Alnico V magnets to create a controlled magnetic circuit. A 14-bar commutator armature with laminations of seven slots with a skew of one full slot tends to reduce the latching effect. Extra large brushes mounted in a Melamine holder are used to obtain longer brush life, lower RF noise and a high altitude and voltage rating. Permanently lubricated ball bearings are used. Made by **Air Equipment Co.**, 2248 E. 37th St., Los Angeles 58, Calif.

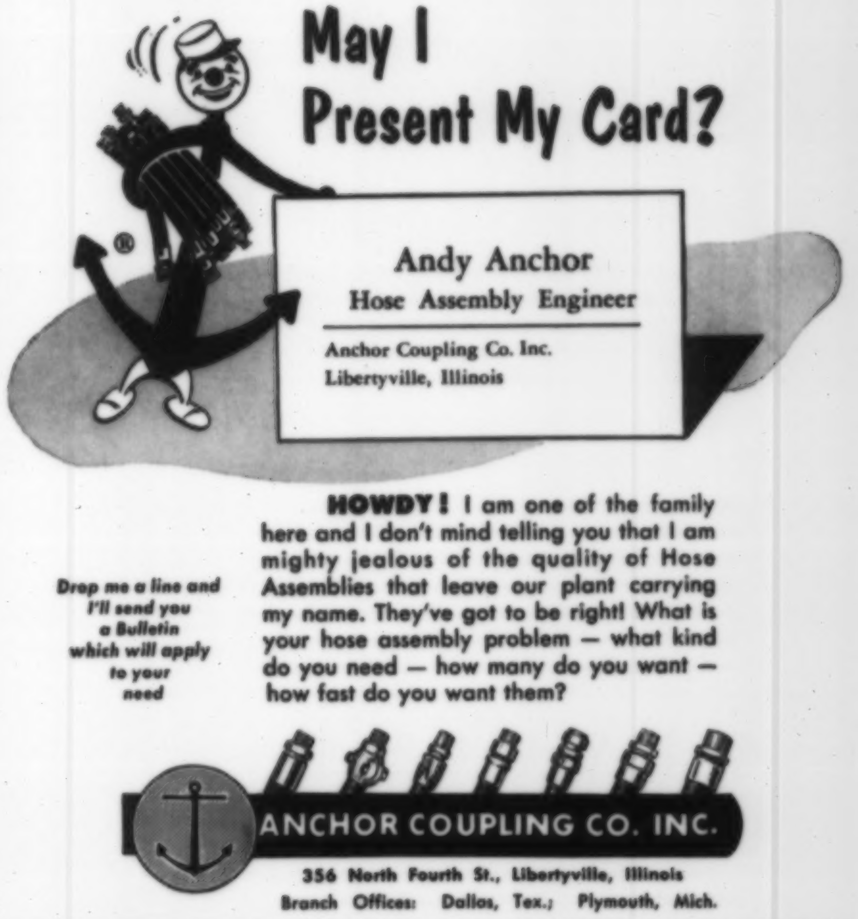
For more data circle MD-110, Page 221

Sectional Terminal Blocks

Series N AlphaBlocks are sectional, hand-assembled terminal blocks consisting of five major interchangeable parts. Any combination of single circuits and distribution strips can be assembled without specially constructed blocks or separated strips. No mounting rails, fasteners or special tools are needed for assembly. Dovetail lugs and slots for joining components are located in the base of terminal blocks, insulating barriers and end pieces to provide automatic self-alignment and strong mechanical connection upon assembly. Dovetail slots are tapered slightly to provide a light press fit between units. Clear plastic insulating covers snap over blocks and fit snugly between insulating barriers. Standard units are furnished with tapped bronze



(*Continued on Page* 276)



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Hose Assembly Engineer
Anchor Coupling Co. Inc.
Libertyville, Illinois

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Illustrated is a Loma Hydraulic Billet Saw equipped with a Ruthman Gusher Coolant Pump.

Why do the leading manufacturers of metal cutting machinery use Gusher Pumps on their machinery? They've found Ruthman Gusher Pumps are dependable — give split second coolant flow from the moment the machine is turned on. And Gusher Pumps require a minimum of attention — they're pre-lubricated, need no priming or packing. Specify Gusher Coolant Pumps — Write us for catalog.

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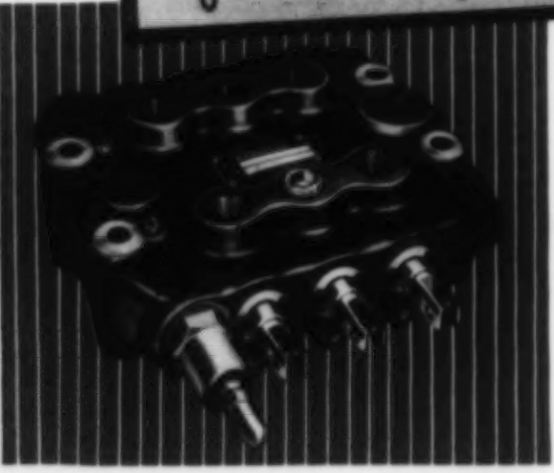
ENGINEER'G

VALVES

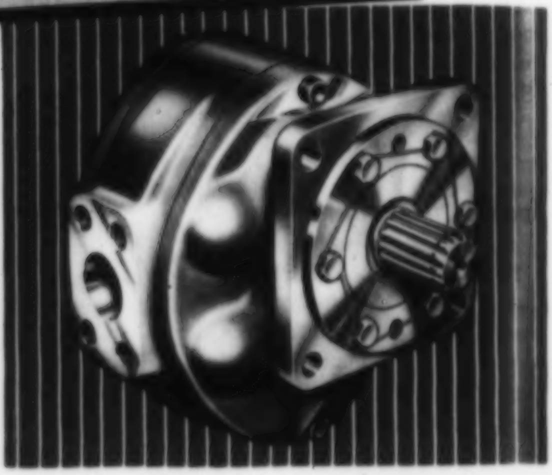
CYLINDERS

Mr. Hydraulics Engineer —
We suggest that you'll want to be familiar with these important developments in Fluid Power . . . products of The New York Air Brake Co.



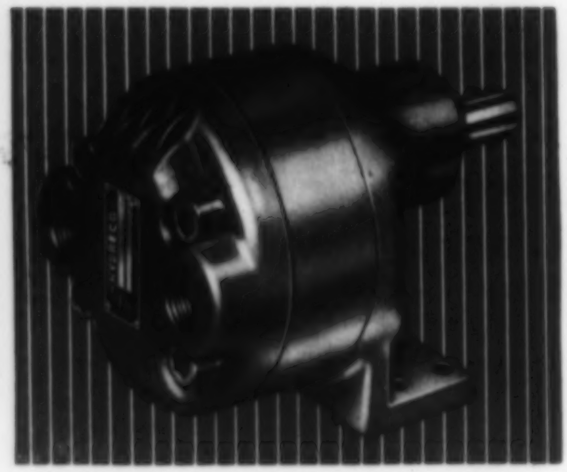
HYDRECO HOLLOW-PLUNGER CONTROL VALVES

The advancements made by HYDRECO engineering in multiple plunger, single and double acting control valves bring you new, accurate throttling . . . smooth, positive, fingertip control with notable freedom from binding, chattering or troublesome back pressures. Valves with 1 to 5 plungers in capacities from 5 to 80 gpm and operating pressures of 1500 and 2000 psi are now available for your present and projected equipment.



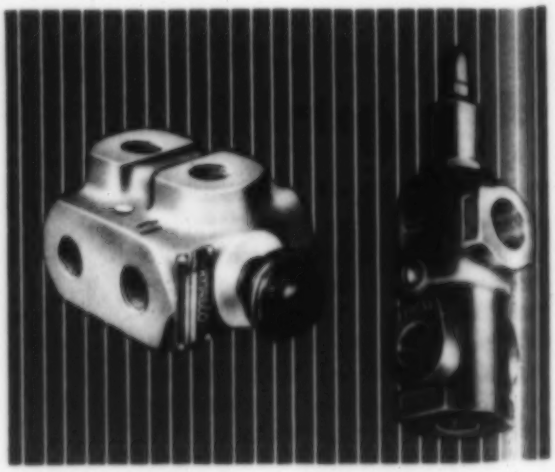
HYDRECO GEAR-TYPE PUMPS 1000/1500 psi

HYDRECO engineers have shattered the illusion that "any gear pump is just a gear pump". New developments in the famous HYDRECO Four-Bolt design provide higher pressures, higher speeds and higher efficiencies than were previously available. You'll want to know more about the many Heavy Duty features in HYDRECO Pumps. A full range of sizes — 3.3 to 55 gpm at 1200 rpm, 1000 psi.



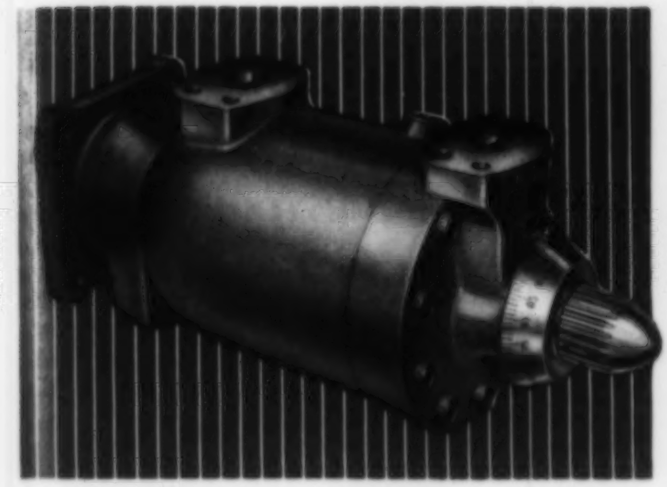
HYDRECO FLUID POWER MOTORS 1000 psi

For the many applications which call for reversible rotary motion with high starting and running torques . . . HYDRECO Four-Bolt, Gear-Type Fluid Motors are the economical and reliable answer. Precision, ruggedness and simplicity combine to ideally suit these motors to machine tools, oil drill rigs, conveyors, agitators and a thousand other uses. Sizes 3 to 17 hp at 2000 rpm, 1000 psi.



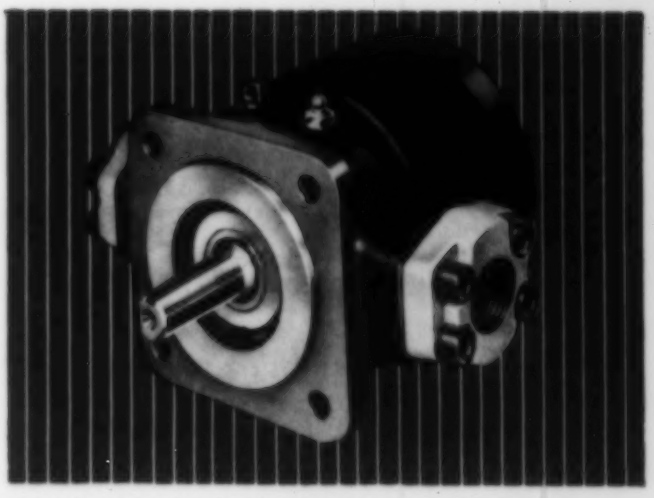
HYDRECO AUXILIARY VALVES 1000/2000 psi

HYDRECO engineers have made very important contributions to the modern hydraulic system in the Relief and Selector Valves now available for your applications. For accurate control over a long service life, HYDRECO Relief Valves in capacities to 80 gpm serve without chatter, squeal or whistle. The Selector Valves enable you to perform additional operations with your system, and these are available in capacities to 50 gpm.



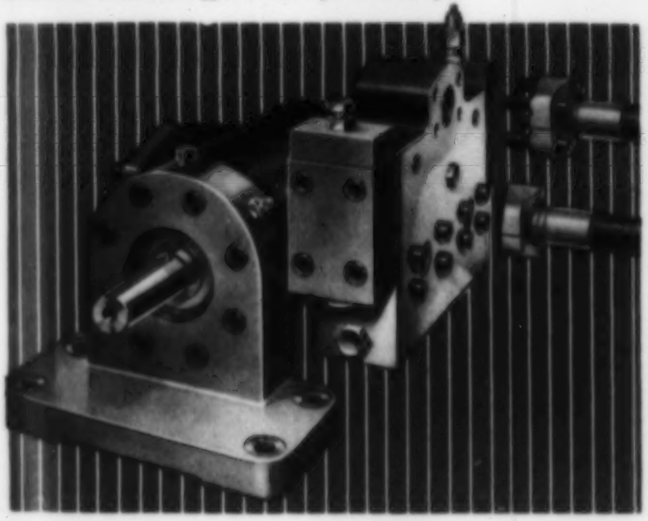
DUDCO VARIABLE DELIVERY PISTON PUMPS 5000 psi

The PV-600 Variable Delivery Pumps give designers a source of Fluid Power that is modern, compact, flexible, efficient and economical. These pumps are offered with two types of Variable Delivery Control. The handwheel Control provides accurate manual adjustment of delivery from zero flow to full flow. The Pressure Compensated Type features automatic pressure and flow control . . . delivery is reduced as pressure in the system reaches a pre-fixed maximum. Delivers 3 gpm at 5000 psi at 1200 rpm.



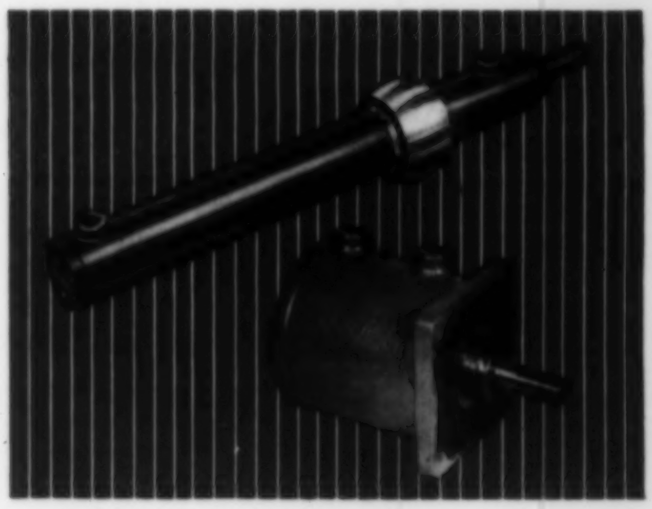
DUDCO DUAL-VANE HYDRAULIC PUMPS 2000 psi

Featuring a simplified, 3-unit construction, these DUDCO PF-100 Pumps provide designers with "a High Pressure Pump at a Low Pressure Price". The fully balanced DUAL-VANE construction assures high efficiency at higher pressures with wear reduced to an absolute minimum. Interchangeable Cam Rings add a factor of flexibility that conserves time and money. Available in flange and foot-mounted models, 3 to 11 gpm at 1200 rpm . . . 2000 psi.



DUDCO DOUBLE PUMPS WITH VALVE PANELS 2000 psi

These integral units meet the broad demands of circuits which call for substantial variation in pump volume, such as: "close and hold" or "traverse and feed" cycles. Hydraulic Presses, Plastic Molding Machines and many Machine Tools find these units highly efficient in operation, low in first cost, dollar-saving in reduced piping and valving in the circuit and supremely simple to service. Can be used in the operation of two separate systems or for Hi-Lo circuits.



HYDRECO CUSTOM-BUILT CYLINDERS

HYDRECO Hydraulic Cylinders enjoy an established reputation for quality and dependability. To achieve this degree of dependability entails craftsmanship and manufacturing niceties not practical in so-called standard cylinders built to meet a price. For engineers who seek performance, long-wear under heavy duty conditions and unmatched leakproof qualities, HYDRECO engineering and craftsmanship have something of special interest to offer.

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SCREW PRODUCTS COMPANY, INC.
GARDEN CITY NEW YORK

(*Continued from Page 273*)

inserts, either with or without internal electrical linkage between pairs. Blocks are 1½ in. wide, 11/16-in. long, 17/32-in. high; barriers are 1¾ in. wide, 5/32-in. long, 1⅛ in. high; ends are 1¾ in. wide, 21/32-in. long, 1⅛ in. high. Units are rated at 50 amp and 750 v. Made by **Alpha Electrical Products Co.,** P. O. Box 202, Little Rock, Ark.

For more data circle MD-111, Page 221

Sealing Flush Bolt

Bolt-O-Seal flush bolt incorporates a rubber sealing gland which seals gases and liquids up to a maximum of 50 psi in standard sizes and styles. For higher pressures, specially ground bolts are furnished for close tolerance counterbores. There is no loss of sealing due to cold flow and rubber cannot be deformed beyond its elastic limits. Faying surfaces have metal-to-metal contact. One-piece assemblies are also available in titanium and with special rubber compounds. Made by **Franklin C. Welfe Co.,** 3644 Eastham Dr., Culver City, Calif.

For more data circle MD-112, Page 221

Mica Capacitors

Micaps are encapsulated and hermetically sealed by a dip coating method rather than by the usual compression molding procedure. They are smaller than molded types and have radial wire leads that provide a short electrical path, making them convenient for

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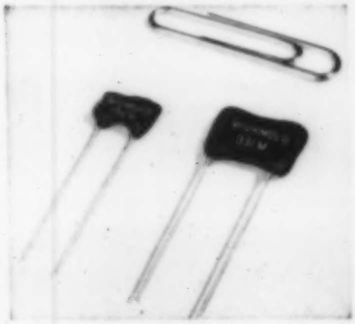

use in subminiature assemblies. Style MQ has a capacitance range of 5 to 30 mmfd, is rated at 500 v dc working, and has dimensions of 7/16 x ¼ x 5/32-in. Capacitance range of style MO is 220 to 1000 mmfd. It is rated at 500 v dc working and measures 19/32 x 13/32 x 3/16-in. Made by **Micamold Radio Corp.,** 1087 Flushing Ave., Brooklyn 37, N. Y.

For more data circle MD-113, Page 221

Protective Coating

Protection against most acid and alkali fumes and splash as well as high humidity, abrasion and weathering is afforded by Neoprene W, a one-component synthetic coating. Applied by brush or spray, coating cures at room temperature. After wire-brushing of metal surfaces to removed dirt, rust and scale, one coat of Neoprene W primer and two coats of Neoprene W are applied for a final thickness of 8 mils on either flat or vertical surfaces. Drying time between coats is 2 to 3 hours and most surfaces can be placed in service after 24 hours. Coverage is 420 mil-feet per gallon. Neoprene surfaces can be recoated or repaired easily. Made by **Carboline Co.,** 331 Thornton Ave., St. Louis 19, Mo.

For more data circle MD-114, Page 221

Filter-Lubricator

Individual protection for air cylinders and small pneumatic tools is provided by the adjustable Nu-Jett filter and lubricator. Installed directly ahead of the pneumatic equipment it protects, it has a per-

(Continued on Page 282)

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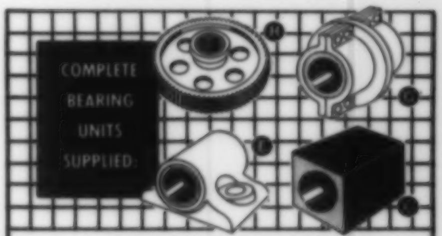

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You can design any welded aluminum parts for your products with confidence because Reynolds Aluminum Fabricating Service can produce these parts and produce them efficiently and economically to your specifications.

Reynolds years of day-in, day-out welding and brazing on a wide variety of jobs—plus continuous developments and experimentation in the use of welding and brazing equipment and techniques—assure you the very highest quality welded and brazed parts.

Look at the photos on these pages. Note the variety of Reynolds welding and brazing operations. Reynolds offers welding equipment ranging from 30 to 800 amp., like the automatic fusion welding equipment shown on the opposite page capable of continuous welding up to 63 inches per minute and featuring built-in crater fillers that permit crater-free welding. Remember, too, Reynolds constant quality control minimizes "down time"—cuts your costs.

For full details on these operations and on the many other services offered by Reynolds Aluminum Fabricating Service, call your Reynolds office listed under "Aluminum" in your classified telephone directory or write *Reynolds Aluminum Fabricating Service, 2061 South Ninth Street, Louisville 1, Kentucky.*

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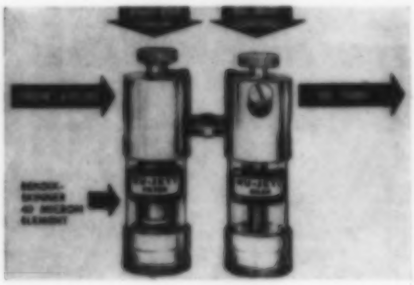
Sure, we make the larger sizes too, but Universal is getting a universal reputation for these Small Balls of such superb accuracy. Want to roll it around and then get in touch with us?

Universal Ball co.
WILLOW GROVE
MONTGOMERY CO., PA.

(*Continued from Page 279*)

manent type filter with Bendix-Skinner 40-micron element which removes all particles as small as 0.0001-in. Filter has pushbutton clean-out at bottom. Lubricator is adjustable to meet exact requirements. Should the primary lubricating means through an oil wick be interrupted, a standby means of syphoning automatically takes over. Air velocity at any setting is unaffected. Made by **Nu-Jett Products Corp.**, 1355 Michigan Ave. N.E., Grand Rapids, Mich.

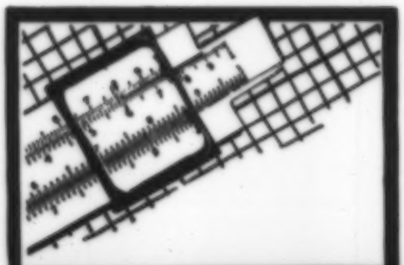


For more data circle MD-115, Page 221

Silicon Power Rectifiers

High-current, low-voltage silicon power rectifiers are approximately 99 per cent efficient. They operate without derating in ambient temperatures of more than 100 C. Hermetically sealed unit occupies about $\frac{1}{8}$-cu in. of space and weighs about 0.1 oz. High efficiency is the result of low voltage drop and reverse leakage current as low as 10^{-10} amp. Various types and sizes of the rectifier are rated from 100 to 500 ma. Maximum forward drop at full rating is less than 2 v, with blocking voltages from 50 to 500 v in the standard ratings and up to 1000 v on special applications. Rectification ratios run as high as 10^8. Made by **Bogue Electric Mfg. Co.**, 52 Iowa Ave., Paterson, N. J.

For more data circle MD-116, Page 221



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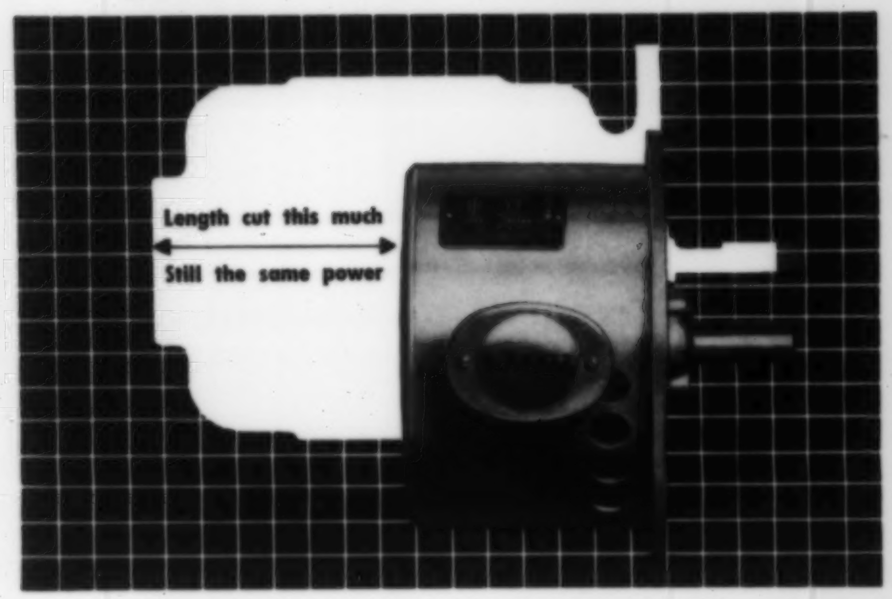
Quick facts for those who design-in and specify electric motors

Disc Motors . . . Space Savers Unequalled!



Here's the way to reduce the space occupied by a motor and still get performance characteristics equivalent to those of a conventionally designed motor. Depending upon horsepower, Howell Disc motors will effect length reductions of between 42 and 50 percent, with only a very slight increase in overall diameter.

This drastic space saving results from flattening the end plates and recessing the bearings into the motor. Howell is one of the few manufacturers who furnish disc motors (sometimes called "pancake" or "wafer-type") as a standard item.

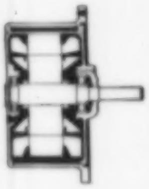


Fig. A

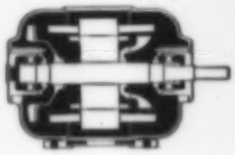


Fig. B

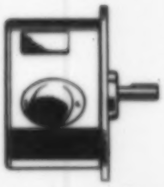
Fig. A, showing the Howell disc motor design, illustrates how the bearings are recessed into the rotor. Compare this with Fig. B, showing conventional motor construction. Both designs provide ample copper wire and lamination steel in the motor.

As compared to other disc motors having the rotor recessed into the stator, Howell's disc motor design has these advantages: (1) Effects a greater reduction in size; (2) Has no axial air gap to vary and cause motor "howl" or power loss, when bearings wear over an extended period; (3) Service, if ever needed, is simplified because of the conventional rotor and stator construction.

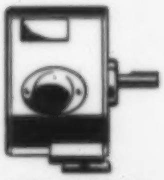
It's a tried and proved design — Howell Disc Motors have been used with excellent results on machine tools, punch presses, cranes and hoists, among many other applications . . . and new uses are being developed constantly. Because there are no ventilation ports in the end plate at the pulley end of an open-type disc motor, it's ideal for vertical, shaft-up mounting.

Howell can furnish all the electrical types available in conventional motors — multi-speed, high torque, high slip; single or polyphase; Class "B" or "H" insulation included. They're readily combined with the Howell friction brake to make an extremely compact and efficient type of brake motor.

They are offered as standard motors in Frame sizes 56 through 32, both in open and enclosed, fan-cooled constructions. Mountings: either NEMA "C" face end plates or foot-type as illustrated.



FLANGE MOUNTING



FOOT MOUNTING

Sizes range from ¼ to 20 h.p. at 1800 rpm, including intermittent hoist types.

Write for Bulletin DT-1

Howell's distinctive motor construction, as applied to the disc type motor, includes such features as these:

High-quality insulation. Seven different pieces of insulation for each slot cell. Complete insulation between top and bottom coils and between all phase groups. Lead wires brazed to coil ends and insulated with vinyl chloride plasticized fiberglass tubing.

Copper-clad rotor. Copper bars and end rings are welded or brazed together for unusual strength. High melting point of copper prevents damage from high temperatures caused by possible over-loads.

Expert craftsmanship. Rotors are ground to precision limits for exact concentricity and uniform air gap. They are dynamically balanced at rated speeds.

High-quality coil varnish. Entire stator is thoroughly impregnated twice with the finest phenolic resin-base varnish, twice baked for extra protection.

Leakproof oil seals. Provide dependable, dirt-free operation.

HOWELL Red Band MOTORS

HOWELL MOTORS

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PRECISION-BUILT MOTORS FOR INDUSTRY SINCE 1915

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Pressure Application — Exact Amounts — Accurately Timed

Engineered to Your Specific Needs

Manzel Force Feed Lubricators meet every requirement for dependable, automatic lubrication on pumps, compressors, engines and other modern machinery. Installations can be made at surprising low cost with any number of feeds and to operate against discharge pressures as high as 30,000 P.S.I.G. And the Manzel organization has the experience and knowledge necessary to work with you in engineering installations to your specific needs. If it's a question of lubrication, write or call Manzel.

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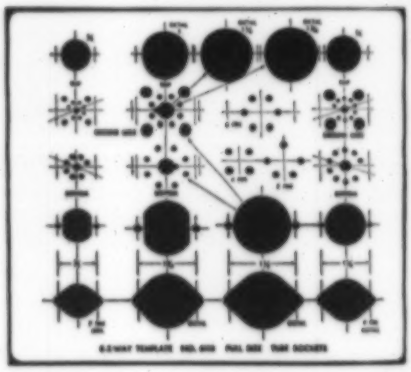
ENGINEERING DEPARTMENT EQUIPMENT

Electronics Templates

Three new templates for use in electronic layouts and schematics are made of 0.030-in. rigid vinyl plastic. Standard dimensions are used, and pencil tolerance is allowed. Horizontal, vertical and centerline indexes, plus nomenclature and sizes, are shown. Template No. 6110, illustrated, contains cutouts for top and bottom views of tube sockets. No. 6120 has cutouts of electrolytic capacitor twistlock bases, and a rotary selector switch which can be used in schematics as well as layouts. Template No. 6116 contains cutouts of standard vacuum tube envelopes. It is used in three-dimensional layouts. Made by **E-Z-Way Templates,** 2242 S. Colby Ave., Los Angeles 64, Calif.



For more data circle MD-117, Page 221

Drafting Instruments

Protractor, T-square, rule, paralleler, compass and dividers are combined in one instrument in these multipurpose drawing aids. One type, available in various sizes, is essentially a straightedge attached to a quadrant with a pivot at its center. Another circular instrument simplifies construction of many geometrical figures, such as five-pointed stars and hexagons, squares and triangles within cir-

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. . . work hardens *much slower* than any of the conventional 18-8 grades

. . . remains *non-magnetic* after severe cold working

. . . possesses corrosion resistance *equal to or better than* standard chrome-nickel stainless steels

This unusual combination of advantages is one reason why Carpenter *Stainless No. 10* is earning a unique place among engineered materials.

For example, it has opened whole new fields of applications in the fastener industry. With its slower work-hardening, fastener manufacturers can now produce on automatic machines severely cold headed and upset chrome-nickel stainless parts without process annealing. *No. 10* is also proving its economy on other jobs involving difficult coining, extrusion and swaging operations.

Another example is instrument parts which must remain non-magnetic after fabrication. After a 50% reduction, with a field of 200 Oersteds, permeability is about 1.002. After an 80% reduction: about 1.018. Will you be *next* to benefit from *Stainless No. 10?* How can *your* stainless product be improved, production simplified, costs lowered? Get the complete story on *No. 10*. Just drop us a line on your Company letterhead. THE CARPENTER STEEL CO., 120 W. Bern St., Reading, Pa.

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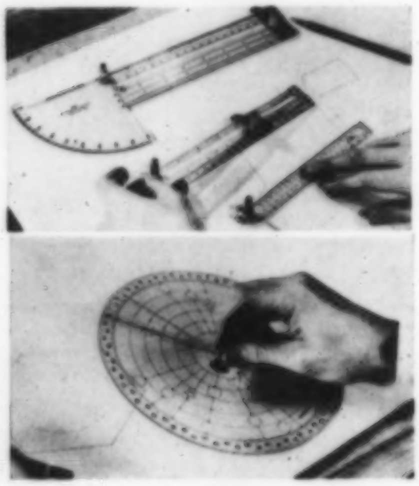
Engineering Equipment

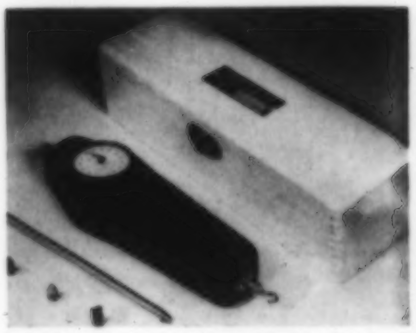


cles having radii from 1 to 3½ in. in ½-in. increments. Both instruments can be used in designing gears, pulleys, cutting tools, machinery or dies and for electrical or electronic layouts. Drafting speed and accuracy result from the use of a retractable pivot point at the center of the quadrant or full circle. Swinging the instrument about its pivot facilitates the construction of arcs, horizontals, perpendiculars, parallels, circles and tangents and aids in bisecting and laying out plane, spherical and compound angles. Made of Bakelite clear, nonwarping rigid vinyl sheet, these instruments resist staining by water, dirt and most chemicals. Finger smudges, ink, pencil marks, grease and dirt can be wiped off with a damp cloth. Made by **Graphic Calculator Co.**, 633 Plymouth Court, Chicago 5, Ill.

For more data circle MD-118, Page 221

Precision Force Indicator

Maximum capacity of this precision force indicator is 30 lb. Shaped for easy hand operation or



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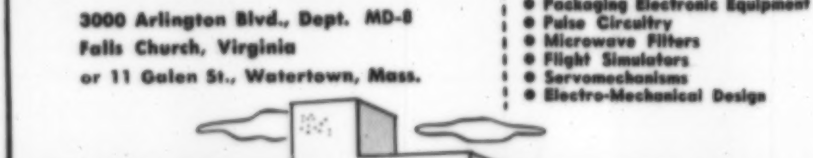
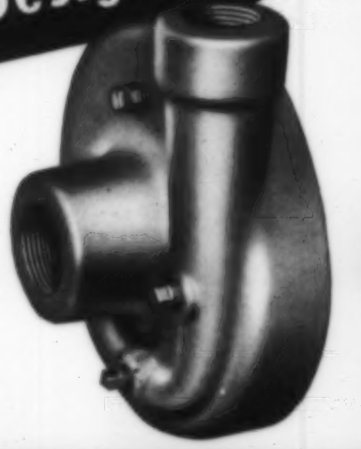
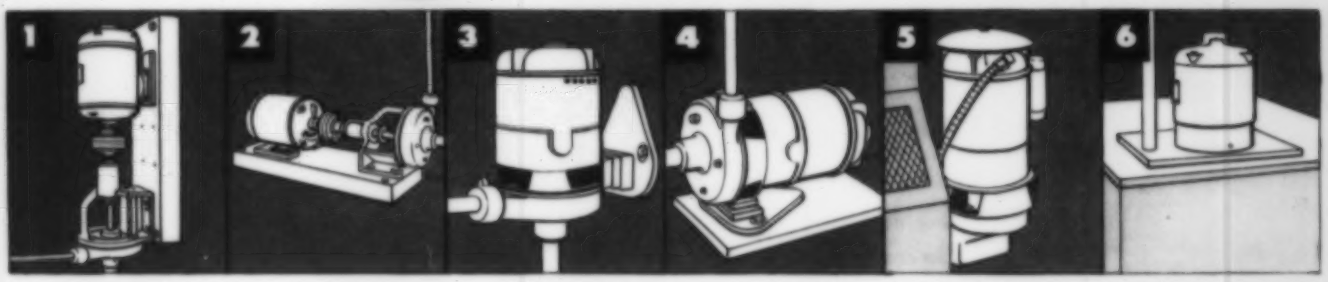
- Pulse Circuitry
- Microwave Filters
- Flight Simulators
- Servomechanisms
- Electro-Mechanical Design



ALLIS-CHALMERS
PUMPS for Designers



One Pump 6 Mounting Methods



Base mounted, vertical | Base mounted, horizontal | Close-coupled, vertically mounted | Close-coupled, horizontally mounted | Tank wall mounted | Submerged mounted

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Choose the pump for exactly the performance characteristics you need; then use the drive and mounting method best suited to your application. Design problems are simplified . . . designing costs and time reduced.

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Your Allis-Chalmers representative is an experienced, highly qualified specialist who will give you full cooperation every step of the way from drawing board to finished product. Sometimes he can make valuable suggestions which will result in a simpler, more effective product. Next time you have a pump problem, call your Allis-Chalmers District Office or write Allis-Chalmers, Milwaukee 1, Wisconsin.

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user of
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- Increases Productive Capacity
- Saves on Repair Bills
- Eliminates Costly Hand Oiling
- Reduces Downtime
- Lengthens Machine Life

WITH Bijur Automatic Lubrication as an integral part of your equipment, your customers benefit from continuous peak production. Plant after plant reports increased out-put and greatly reduced maintenance costs with Bijur-equipped machines. Costly downtime for lubricating by hand is eliminated. Every bearing is metered the proper quantity of oil at predetermined intervals. Work spoilage and bearing troubles caused by over-lubrication are avoided. Fire hazards are reduced. Personnel accidents are prevented.

Bijur gives you the opportunity to add customer satisfaction through improved machine performance.

More than a million Bijur-protected machines are in use. Hundreds of leading manufacturers standardize on Bijur as "built-in" components of their machines. Bijur emphasizes custom-engineering, and we will gladly co-operate in designing a system to meet the specific requirements of your machine.

Design Bijur into your machines now in production or in the planning stage. Write for literature and engineering information.

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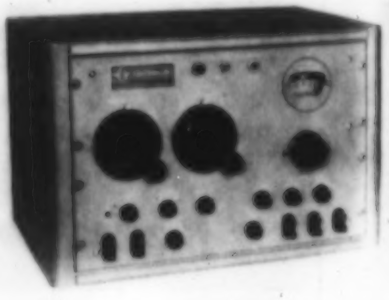
Rochelle Park, New Jersey

for use in permanent test setups, it is provided with six stainless steel attachments for the accurate measurement of many types of linear and rotational forces. Device employs a compensated spring mechanism which holds gradient error to 0.10-per cent, and a fully jewelled dial indicator. Overall accuracy is one-half of one scale division, or equivalent to ± 2 oz. Made by **Hunter Spring Co.**, Lansdale, Pa.

For more data circle MD-119, Page 221

Swept Frequency Generator

Model 200K swept frequency generator is used in conjunction with an Electromec large screen oscilloscope to provide an instantaneous and continuous visual display of frequency response of a device under test. Effects of changes in circuit parameters upon frequency characteristics can be determined instantly. The generator produces a constant amplitude output voltage, continuously varying in frequency, and covers a frequency range from 20 cycles per second to 200 kc or any increment of this range. Continuous frequency variations are produced by the modulation of a voltage controlled oscillator with internally generated sawtooth, triangular or square wave forms at any rate between 0.5 and 50 cycles per second. Provision is made for external modulation. A frequency marker, accurate to ±0.1 per cent, can be set for any frequency within the range of the instrument. Mountable in a standard 19-in. relay rack, the unit requires 12¼ in. panel space. Made by **Electromec Inc.**, 3200 N. San Fernando Blvd., Burbank, Calif.



For more data circle MD-120, Page 221

THE ENGINEER'S

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Recent Books

Magnetic Control of Industrial Motors. *By Gerhart W. Heumann, industry control department, General Electric Co.; 726 pages, 5¾ by 9 inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, *$9.50 postpaid.*

Now in its second edition, this book contains analyses of all modern types of motor control and data on their engineering applications. It includes new material on adjustable voltage and regulating systems, particularly with regard to rotating and magnetic amplifiers. The theoretical background underlying recognized national standards and safety codes has been emphasized. Considerable stress has been placed on explaining the rules of the National Electrical Code which apply to motor controllers.

In 20 chapters this book covers symbols and diagrams, principles of dc and ac motor operations, dc and ac contactors and relays, accessories, pilot and electronic devices, resistors and rheostats, construction of control panels, basic dc and ac control circuits, amplidyne control circuits, protection, solenoids, thrustors, brakes, manual and general-purpose controllers, dc and ac intermittent-duty controllers, and maintenance of control equipment.

The book is amply illustrated with photographs, charts, and diagrams. References are given at the end of most chapters.

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Model Analysis of Structures. *By T. M. Charlton; 156 pages, 5½ by 8½ inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, *$5.00 postpaid.*

This book is concerned with

Distortion is Controlled in BRAD FOOTE'S DEEP CASE HARDENING

The BRAD FOOTE DEEP CASE HARDENING process has been perfected to a degree which practically eliminates distortion

Certified Brad Foote Products

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No place is distortion control more important than on heavy duty gears which are run almost continuously at full rating and subjected to extreme shock loads such as are encountered in rolling mill operations. BRAD FOOTE DEEP CASE HARDENED gears run true and distribute the load evenly across the full face and on the designed bearing surfaces of each tooth.

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In addition, BRAD FOOTE rigidly controls to set standards the depth of DEEP CASE HARDENING and the carbon content. The tooth surfaces are of maximum hardness for long life, but the carbon content is gradually diminished at successive depths below the surface until it blends to the metal of the core itself.

SHOCK-RESISTANT CORES

Thus the cores of the teeth and the body of the gear remain ductile and shock-resistant while the teeth are given an increase in service life of over 50%.

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It will pay you to try a set of these gears on your toughest job. Send your specifications today for quotation.

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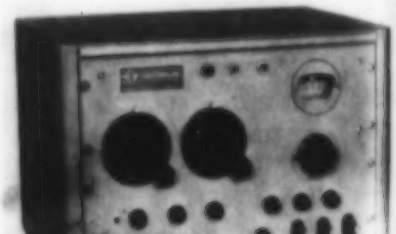

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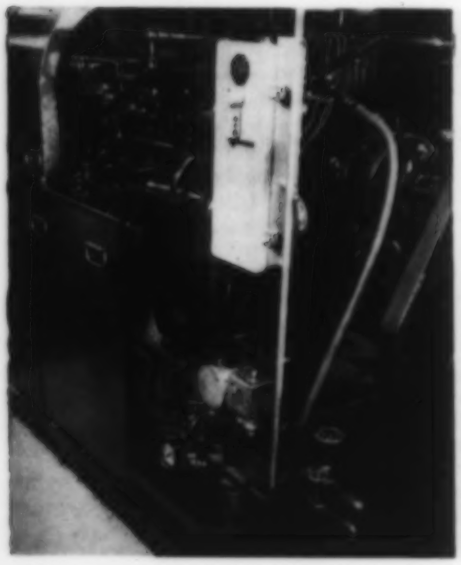
how a Lubrication Engineer converted to
Norgren Micro-Fog Lubrication
of an automatic screw machine

RESULTS:
- increased life of bronze slide blocks
- ½ pt. oil does better job than 15 gal.
- reduced machine maintenance

A 3000 rpm automatic screw machine, used by a leading manufacturer of electrical automotive equipment, was formerly equipped with circulating oil system and used fifteen gallons of oil per day. There was a considerable oil loss due to splashing and to leakage from the bearings.

A Norgren Lubro-Control Unit (Model 3765AV-2) was installed to lubricate the sleeve bearings, antifriction bearings, slide blocks, guides, chucking mechanism and gears.

RESULTS: Just ½ pint of oil per day through the Norgren Micro-Fog Lubricator does a better lubrication job than 15 gal. of oil with the circulating system ... life of bronze slide blocks was substantially increased ... machine maintenance was noticeably less.



An Automatic-Drain Air Filter (Model 11,200-2(25)) prevents contamination of oil supply; a Regulator (Model 2A2GG) reduces main line pressure to proper working pressure; a Lubricator (Model 30-41-2S) delivers an air-borne Micro-Fog to all bearing surfaces. A solenoid valve starts and stops the Micro-Fog system when the machine is turned on and off. A pressure switch turns off the machine automatically when air pressure drops below a safe operating value.

DESIGNERS... you can add many important sales features to your machine tools with Norgren Micro-Fog Lubrication... types and sizes of lubricators for both small and large machines, with capacities up to 1000 bearing inches.

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For details on the above and other machine tool applications and technical information on system design, write for Norgren
Blueprints MF10 through MF18.

Oil Fog Lubricators • Pressure Regulators • Air Filters • Valves • Hose Assemblies

theoretical principles and techniques of methods of analyzing engineering structures having linear load-deflection characteristics with the aid of scale models. The methods have been selected on grounds of their being easy to employ with speed and accuracy, without expensive tools and apparatus. Particular attention is paid to principles of similarity which govern the design of models and by which the results of tests are interpreted for the prototypes.

Discussed and illustrated in seven chapters are similarity of structures, principles of model design, theory and technique of the indirect model method, analysis of a portal frame by the indirect method, and some direct methods of model analysis and their application.

•

A Dictionary of Electronic Terms. *Edited by Gordon R. Partridge, associate professor of electrical engineering, Purdue University; 72 pages, 6 by 9 inches, paperbound; available from Allied Radio Corp., 100 N. Western Ave., Chicago 80, Ill., under stock number 37 K 756, 25 cents per copy.*

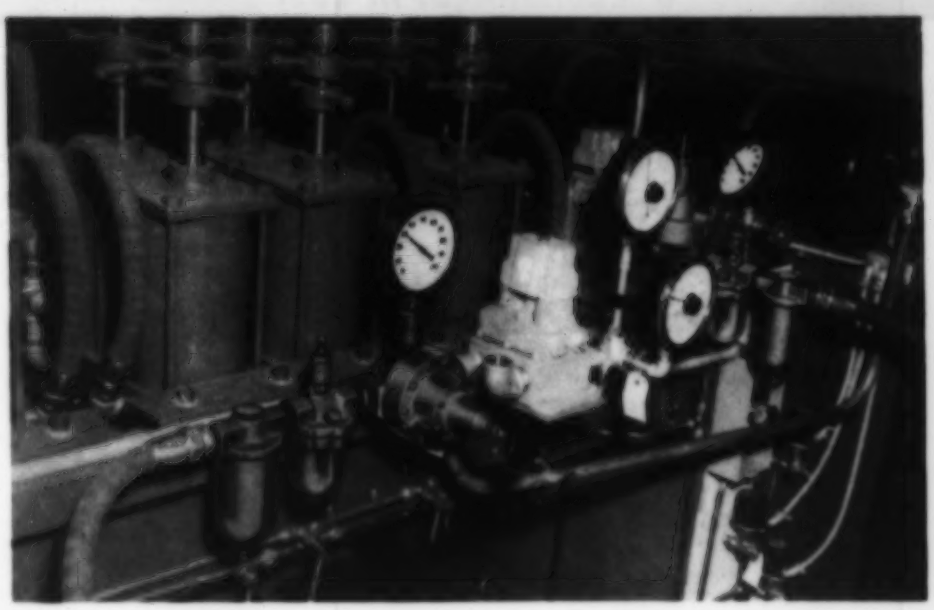
The revised edition of this publication contains definitions of over 3500 terms used in television, radio and industrial electronics. It is intended to serve as a reference guide for engineers, industrial electronic specialists, research men and students. Over 150 illustrations and diagrams of components, equipment and electronic circuits are included.

•

Fluid Dynamics of Jets. *By Shih-I Pai, associate research professor, University of Maryland; 243 pages, 6 by 9 inches, clothbound; published by D. Van Nostrand Co. Inc., New York; available from* MACHINE DESIGN, *$5.00 postpaid.*

This book covers jet flow from fundamentals to such advanced topics as laminar and turbulent flow of compressible fluid, and properties of turbulence fluctuation. It presents practical applica-

how NORGREN air-pressure regulators improve machine performance, cut costs



Portion of a Sciaky Electric Resistance Welder, for welding automobile radiators, equipped with nine Norgren units.

SCIAKY uses NORGREN pilot-controlled regulators on welders

provide accurate air regulation essential to produce uniform welds of high quality

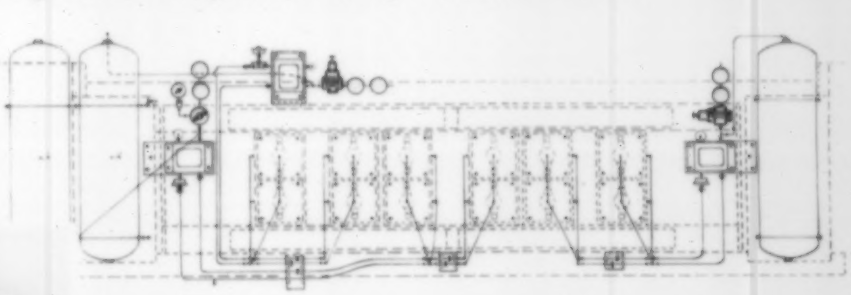
Sciaky Bros., Inc., largest manufacturer of electric resistance welding machines, has used Norgren equipment since it started manufacturing in the U. S. in 1939. Every welder they produce includes some Norgren components . . . filters, regulators, lubricators or hose.

Sciaky selected Norgren Pilot-Controlled Regulators because they provide the dependable, accurate air regulation necessary to produce uniform welds of high quality, and provide the large volume of air flow necessary to operate the many cylinders incorporated in their equipment.

The Series 20AC and 20AA Regulators were originally developed by Norgren for the welder industry. These pilot-controlled units provide extremely accurate pressure regulation, with high air flow capacities.

REGULATORS ESSENTIAL ON AIR-OPERATED EQUIPMENT

Norgren Pressure Regulators are being used on boring mills, air-powered pumps, pressure generators, presses, clamping cylinders, air chucks and many air tools. They pay for themselves in savings in air costs alone . . . and, provide accurate air regulation essential to high operating efficiency and long equipment life, with minimum maintenance costs.



Air Circuit drawing for Sciaky Welder shown above. Norgren Lubro-Control Units filter the air, regulate the air pressure to 12 cylinders and provide oil-fog lubrication for cylinder walls and piston packing.

C. A. Norgren CO.
3442 So. Elati, Englewood, Colo.

- Oil Fog Lubricators
- Pressure Regulators
- Air Filters
- Valves
- Hose Assemblies

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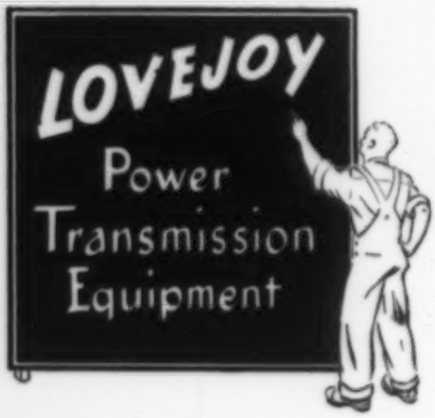
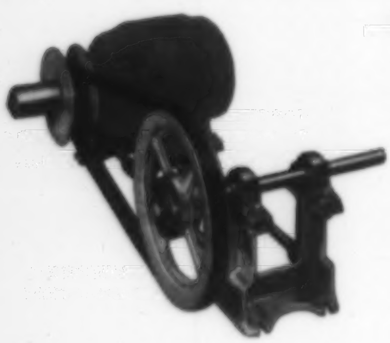


• Economical in Cost
• Easily Installed
• Efficient, Long Lasting



VARIABLE SPEED PULLEYS:

Quickly installed on new or old equipment. Change speed while machine is running. Ratios to 3 to 1. Fractional to 10 hp.

SELECT-O-SPEED TRANSMISSION:

Economical as compared to other variable speed transmissions. Instant adjustment over wide range of speeds. Hand wheel or lever control. Ratios to 10 to 1. Fractional to 5 hp.

FLEXIBLE COUPLINGS:

No lubrication required. Provide positive protection against vibration, torque, shock of intermittent loads. Cushions changed without shutdown. Light, medium and heavy duty: fractional to over 2400 hp., 10 to over 1200 rpm.

UNIVERSAL JOINTS:

Precision ground. Finest alloy steel. No binding, backlash or end play. 13 sizes. Diameters ½ to 4 in. Bores ¼ to 2 in. Lengths 2 to 10⅝ in.

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tions for engineers engaged in problems of propulsion, external flow, and testing live rockets and jets, as well as those working on jet pump design, flow mixing processes, heat transfer, hydraulics and air pollution.

Subjects discussed in 9 chapters include flow of a jet of inviscid and incompressible fluid, subsonic and supersonic flow of a jet of inviscid fluid, laminar flow of a jet of viscous fluid, turbulent flow of jets of incompressible and compressible fluids, jet mixing of gases, and stability of jets of incompressible and compressible fluids. An appendix presents fundamental equations of fluid dynamics.

New Standards

ASTM Standards on Copper and Copper Alloys. 598 *pages,* 6 *by* 9 *inches, cloth or paperbound; available from American Society for Testing Materials,* 1916 *Race St., Philadelphia* 3, *Pa.,* $5.00 *per copy paperbound,* $5.65 *clothbound.*

This latest edition is intended to present in convenient reference form the various ASTM standard and tentative methods of test and specifications pertaining to copper and copper-base alloy products. Standards cover specifications for electrical conductors; plate, sheet, rolled bar, and strip; rod, bar and shapes; nonferrous metals; wire, pipe and tube; ingot; sand and die castings; filler metal; and methods of test for copper and copper alloys.

Association Publications

Heat Treatment of Gray Iron. *By C. O. Burgess, former technical director, Gray Iron Founders' Society;* 123 *pages,* 6 *by* 9 *inches, paperbound; available fram Gray Iron Founders' Society Inc.,* 930 *National City-East 6th Building, Cleveland* 14, *O.,* $5.00 *per copy, or* $2.50 *to society members, public libraries and schools.*

This manual contains a full description of gray iron heat-treating procedures. It includes sections on stress relieving, annealing, induction hardening, flame heardening, full hardening and tempering. Numerous examples are illustrated and described.

A purpose of this booklet is to indicate how the application of heat treatment can be expanded to make gray iron meet the increasingly stringent demands of industry.

•

A Professional Look at the Engineer in Industry. 136 *pages,* 6 *by* 9 *inches, paperbound; available from the National Society of Professional Engineers,* 1121 15*th St., N.W., Washington* 5, *D. C.,* $3.00 *per copy.*

Prepared by the NSPE Engineer-in-Industry Committee, this publication brings together pertinent facts about the background and present situation bearing on the future professional development of engineers employed in all types of industry. Related effects on all other professional engineers are also discussed. It presents a challenging program to bring about improvements in the professional and economic position of engineers in industry without resort to collective bargaining.

•

Fundamentals of Friction and Lubrication in Engineering. 196 *pages,* 5½ *by* 8½ *inches, paperbound; available from American Society of Lubrication Engineers,* 84 *E. Randolph St., Chicago* 1, *Ill.* $3.50 *per copy, or* $3.00 *for ASLE members.*

This recent publication presents the proceedings of the First ASLE National Symposium, held in September, 1952. The 12 papers presented at this symposium review important aspects of hydrodynamic and mixed film lubrication; engineering application; roll neck bearings; vertical pivoted-shoe thrust bearings; gear teeth; physics and chemistry of rubbing solids; graphite and other layer-latticed solids; wear fragments; and solid sliding contact.

These papers, all published for the first time, include bibliographies with over 300 references.

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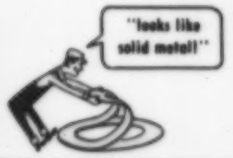
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The little tab holds shim laminations together firmly, yet is easily removed. Different metals can be used in the same shim.

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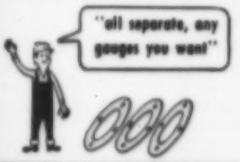
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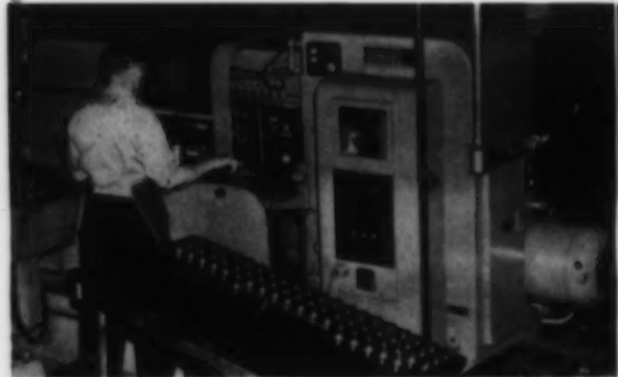
Century Performance-Rated Motor provides heavy duty muscle power for this large shear.

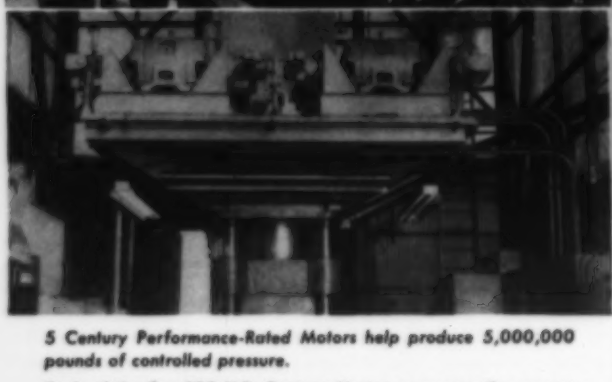
The ability to handle heavy shock load was an important factor in the selection of a Century Motor with proper torque and speed for this application.

Century Performance-Rated® Motors for

Century Performance-Rated Motor helps get production out fast on 5-spindle automatic chucking machine.

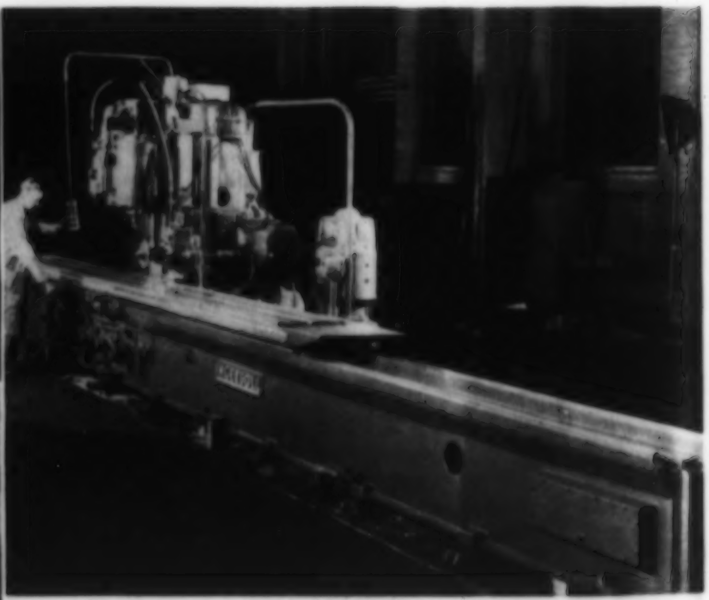
In the selection of a Century Motor, all the factors were Performance-Rated to match the specific application—speed, torques, mounting and frame protection.





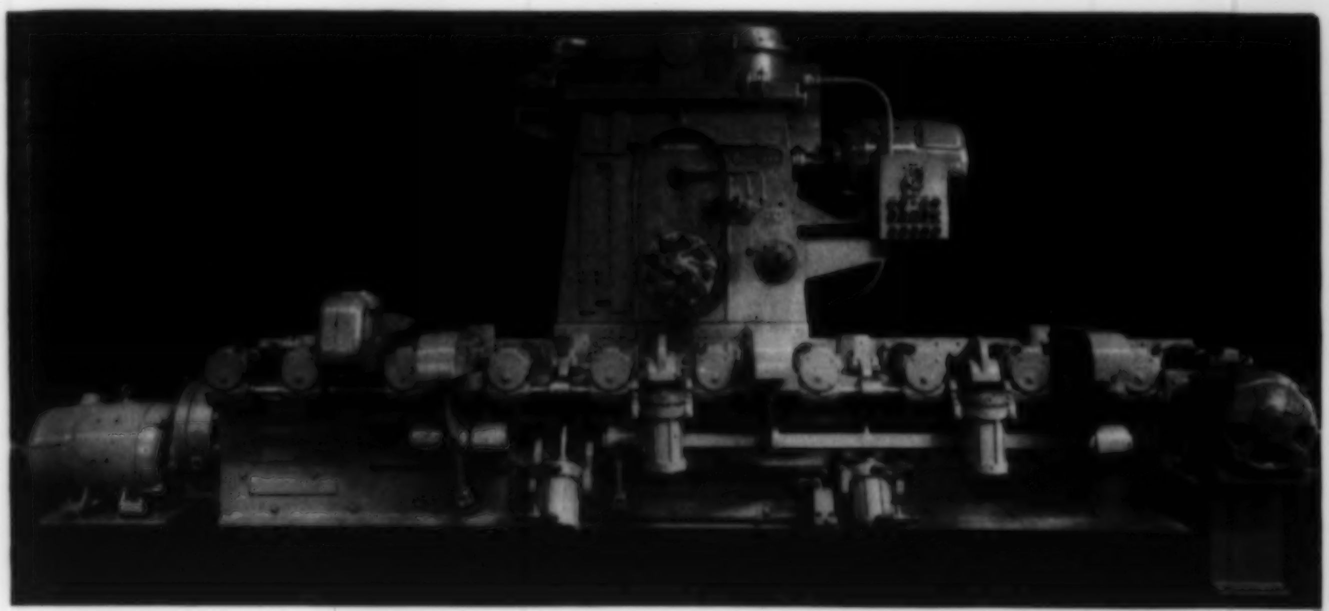
5 Century Performance-Rated Motors help produce 5,000,000 pounds of controlled pressure.

Each of the five 100 H.P. Century Motors possesses the proper torques and speed to help this giant press operate profitably.



5 Century Performance-Rated Motors help bring out the best performance from this 22-ft. keyway slotter.

With each motor engineered for top performance in its own specific job, the 5-motor Century team contributes to cost-saving operation of this important unit.



15 Century Performance-Rated Motors are the power team for fast skinning of high-chrome steel billets.

These *Performance-Rated* Century Motors provide ample power for skinning "52100" high-chrome steel billets at a rate of 2900 sq. in. per hour.

Modern Ideas

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Leading designers will tell you that much of the precision and efficiency of modern machine tools depends on motors properly "fitted" to the job. In many cases, these are Century Motors. Because they are Performance-Rated, Century Motors provide an unequalled wide range of speed, torque, mounting and frame characteristics. When properly selected, they bring out the best performance in any machine.

Get full value from your investment in new equipment . . . specify Century Motors! For Performance-Rated replacement motors, call your nearby Century authorized distributor or contact our District Sales Office.

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STEEL TUBING
Improves Performance Standards
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LET US QUOTE ON YOUR TUBING AND FABRICATION NEEDS

Avon single wall steel tubing is successfully supplanting other types of tubing—aluminum, brass, copper and steel—with equal or improved reliability of performance and really impressive economies.

Avon's High Frequency Fusionweld process insures a much higher degree of tensile strength, greater resistance to vibration and fatigue, extreme ductility, plus greatly improved adaptability in producing the most critical tube forms—such as beading, bending, coiling, flaring, knurling, slotting, piercing, threading and swaging without cracking, tearing or checking.

Avon engineers can assist with your tubing problems and help point up cost saving advantages. Why not write, or submit blueprints for quotations.

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AVON TUBE DIVISION

3/16" O.D. to 3/4" O.D.
PLAIN OR TERNE COATED

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- Lubrication lines
- Fuel lines
- Fuel manifolds

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Stress Relief

THIS month J. P. Henderson winds up his series on the engineering convention and, after considering various side issues that divert the delegates, really gets down to the serious business at hand.

Cocktails and Technical Sessions

One of the highlights of the engineering convention is the cocktail party. I am not referring now to the innumerable small ones that go on here and there—but to the Big One for all members. This usually precedes the annual smoker or banquet.

I would advise strongly that you attend this affair, even if you do not touch the stuff. It gives you one of those opportunities to observe engineers *en masse*—with their guards down.

Human Engineering and the Decibel Level

One of the things that distinguishes engineering groups and identifies them at once as being engineers, physicists, chemists or others of like persuasion is their absence of small talk.

When you've visited a hotel, have you noticed persons with badges busily chatting in groups or shouting to other groups all over the place? They are comparative strangers but they are convention delegates—morticians, realtors, insurance salesmen, and so on, but *not* engineers.

In contrast observe the engineering convention. Delegates can be identified at once by the uncomfortable manner in which they stand around, having nothing to say to each other. Here and there a group of old friends might speak in low tones.

The cocktail party starts off like that. Subdued voices, nothing to say to comparative strangers. A decibel meter in the room would scarcely register.

Observe again an hour or so

How a shift in gears saved $256,000

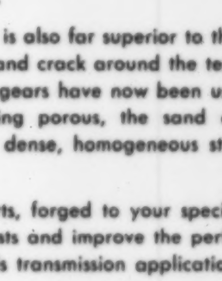
Five million MUELLER BRASS CO. forged ring gears improve automatic transmission operation . . . at lower cost to the manufacturer.

Ever since one of the leading manufacturers of automotive transmissions began using ring gears forged from Mueller Brass Co. bearing bronze, production costs have been cut nearly $256,000. That's because the rough forging weighs less and is closer to finished size than a sand cast ring gear formerly used. This shift in gears resulted in a savings in metal costs, greatly reduced machining time and increased tool life. In addition, the use of forged gears has cut scrap loss and eliminated costly inspection rejects.

The performance of these forged ring gears is also far superior to the sand cast gear, which had a tendency to flake away and crack around the teeth, causing failures. More than five million forged ring gears have now been used in these transmissions without a single failure. Being porous, the sand casting was difficult to balance, but the forging has a dense, homogeneous structure that helps keep it in perfect balance.

Strong, long-wearing non-ferrous metal parts, forged to your specifications by Mueller Brass Co., can help reduce your costs and improve the performance of your products just as they have done in this transmission application. For complete information, write us today.

Write today for your complete set of Mueller Brass Co. engineering manuals.



MUELLER BRASS CO. PORT HURON 15, MICHIGAN

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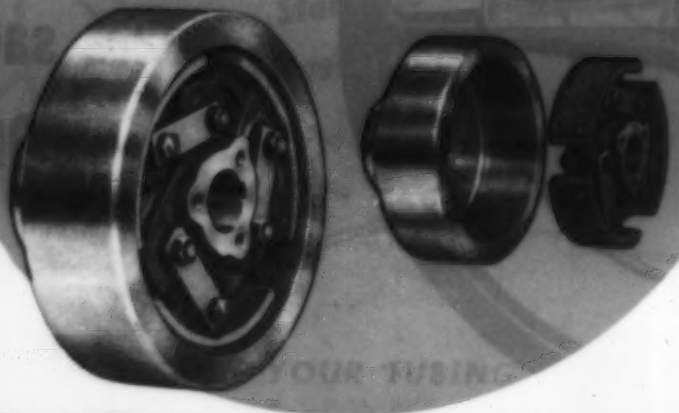
Flexible ACTION IN THE New HILLIARD TWIFLEX
AUTOMATIC CENTRIFUGAL CLUTCH COUPLING



11 NEW IMPORTANT FEATURES..

1. Flexible in all directions.
2. Absorbs Shock.
3. Limits torsional vibration.
4. Has adjustable idle speed.
5. Can be furnished in automatic free-wheeling type.
6. Smooth starting.
7. No slip under normal load at full speed.
8. Protects driver and driven mechanisms against overload shock.
9. Can be furnished in automatic back-stop type.
10. Prevents torsional resonance.
11. Easily assembled even in blind installations.

If you have problems of misalignment — smooth starting — vibration — overload — or assembly in the manufacture or operation of:

- Compressors
- Blowers
- Diesel Engines
- Excavators
- Refrigeration
- Hammer Mills
- Textile Machinery
- Wire Machines
- Fans
- Gasoline Engines
- Back Stop Brakes
- Mixers
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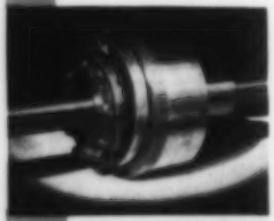
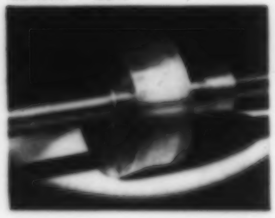
- Pumps
- Electric Motors
- Generators
- High Speed Pulverizers
- Tube Mills
- Let Our Engineers Consider Your Problem. Twiflex May Be The Answer.



SINGLE REVOLUTION CLUTCH
For automatic, accurate control, electrically or mechanically, of intermittent motion, indexing, cycling, cut-off. Write for Bulletin #239.

OVER-RUNNING CLUTCH
For automatic engagement and release on two speed drives, dual drives and for ratchet feed or backstop action. Write for Bulletin #231.



SLIP CLUTCH
For overload protection—constant torque—constant tension on reeling or winding stands. Write for Bulletin #300.

WRITE TODAY! For Details of TWIFLEX Coupling in Catalog CE-3

THE HILLIARD Corporation
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later. Better still, as a scientific experiment, take a decibel reading every half-hour during the party. Noise level goes up probably as the square or cube of elapsed time.

Consider the contrast—after an adequate interval the engineers probably make as much noise as automobile salesmen would have made at the beginning of their party. Engineers have been noted for their nongregarious, antisocial habits, but an old crony of mine defends the engineer on this point. He insists that the engineer is really a sociable fellow, friendly and affable, except that he was born in the neighborhood of two drinks below par.

The Speaker's Rostrum

Up to this point we have paid no attention to the presumable real point in getting this convention together—the technical sessions and the papers. Professional papers are being presented daily all over the place in various meeting rooms.

It might be well if you, as a delegate, would look over the program. Select some meeting and sit in for a short time. You might learn something—if nothing else than the obvious fact that engineers are notoriously poor speakers, and that the gist of a lot of scientific work can scarcely be presented intelligently in the 15 minutes or so allowed.

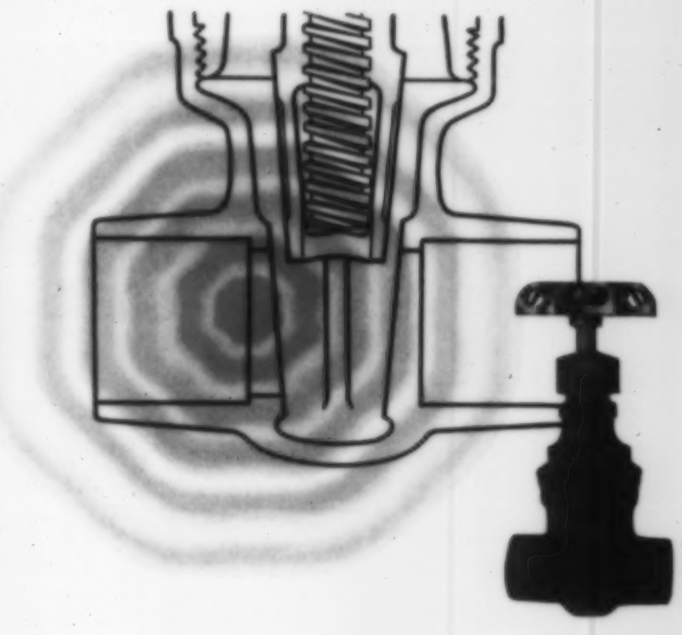
Fortunately, copies of all of the papers are available so that you can buy those related to your work and study them over leisurely at home. I would strongly advise that an impressive handful be purchased. Taken to the office on your return, they are something tangible from your trip.

If, by chance one of these papers was presented during the session you attended, it would be well to pass out a few remarks like "old Beechly did a pretty good job of explaining this paper during the meeting." This will impress your boss and associates. A young engineer who goes to conventions and attends a technical session might possibly get sent again sometime.

—J. P. HENDERSON

When the heat's on

you need the extra strength of JENKINS Solder and Socket End VALVES



Solder End GLOBES and ANGLES

300 lbs. O.W.G.
¼" to 3"

Fitted with Renewable Composition Disc.

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225 lb. and
300 lb. O.W.G.
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With solid or split wedges, and stationary or traveling spindles.

Solder End CHECKS

300 lbs. O.W.G.
¼" to 3"

Regrinding. May be easily reground without removal from line.

NEW BULLETIN Lists all Jenkins Solder End and Socket End Valves and gives complete instructions for soldering and brazing. Ask for Solder-Socket End booklet.

The "light-duty" look of copper tubing installations is deceiving. Valves must provide an accurate fit to tubing and *hold it* under the intense heat of soldering. And, because flexible tubing does not afford the rigid support of standard pipe, valves must withstand unusual strains in operation.

Jenkins Solder End Valves are engineered to meet these demands with strength to spare. High tensile bronze castings have liberal dimensions for extra rigidity. Smooth, clean bores assure accurate fit, easy soldering, positive seal to types K, L, and M Copper Tubing.

For faster, trouble-free installation, and lasting economy, specify Jenkins Solder End Valves. Jenkins Bros., 100 Park Ave., New York 17.

JENKINS Socket End Valves

for Class B or IPS Tubing

Jenkins bronze valves with socket ends for silver-brazing are made in Globe, Gate, and Swing Check patterns to control compressed air, hot oil, and similar fluids in tubing hookups where specifications call for permanent, leakproof joints. Complete information in the Bulletin offered below.

JENKINS

LOOK FOR THE JENKINS DIAMOND

VALVES SINCE 1864 JENKINS

Jenkins Bros

SOLD THROUGH LEADING INDUSTRIAL DISTRIBUTORS

Ingeniously Designed
WISCONSIN-POWERED

LAD-E-VATOR hoist
CUTS
COSTS

Speeds Up
Materials Handling

Here is an interesting, effective application of a Model AEN (4½ to 8¼ hp.) Wisconsin Single Cylinder Heavy-Duty Air-Cooled Engine . . . for easy, one man, one hand control of an extension hoist for lifting and dumping loose materials up as high as 80 ft. in one minute, according to the builders, Campbell Equipment Co., Chicago, Ill.

This equipment, shown here pouring concrete, will handle all kinds of loose and bulk materials, delivering them right to the working area for automatic dumping or removal by workmen. Designed for use on construction or storage jobs, the Lad-E-Vator eliminates dangerous swinging buckets and risky reaching operations. Can be used with platform, wheelbarrow or scoop, carrying up to 1000 lbs. per load. Supplied in various types of units, each of which employs a Wisconsin 4-cycle single cylinder heavy-duty air-cooled engine as standard equipment.

The Wisconsin-powered winch is mounted at the base of the hoist, out of the way, behind the Lad-E-Vator where it is fully accessible . . . typifying the adaptability of these compact, rugged engines to fit both the Job and the Equipment. Heavy-Duty design and construction, tapered roller bearings at BOTH ends of the crankshaft, gear-driven high tension OUTSIDE Magneto equipped with Impulse Coupling for quick starts in any weather at low cranking speed . . . these are some of the features that stand back of Wisconsin "MOST H. P. HOURS" of on-the-job service, with minimum servicing.

You can't do better than to specify Wisconsin Air-Cooled Engines for any equipment requiring heavy-duty power within a 3 to 36 hp. range. Our engineering department will be glad to cooperate with you. For further data, write for Bulletin S-164.

MOST H.P. HOURS

WISCONSIN MOTOR CORPORATION
World's Largest Builders of Heavy-Duty Air-Cooled Engines
MILWAUKEE 46, WISCONSIN

A 8323-1½

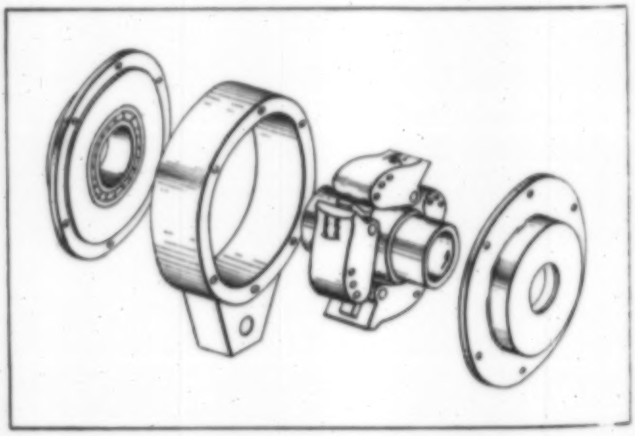
NOTEWORTHY Patents

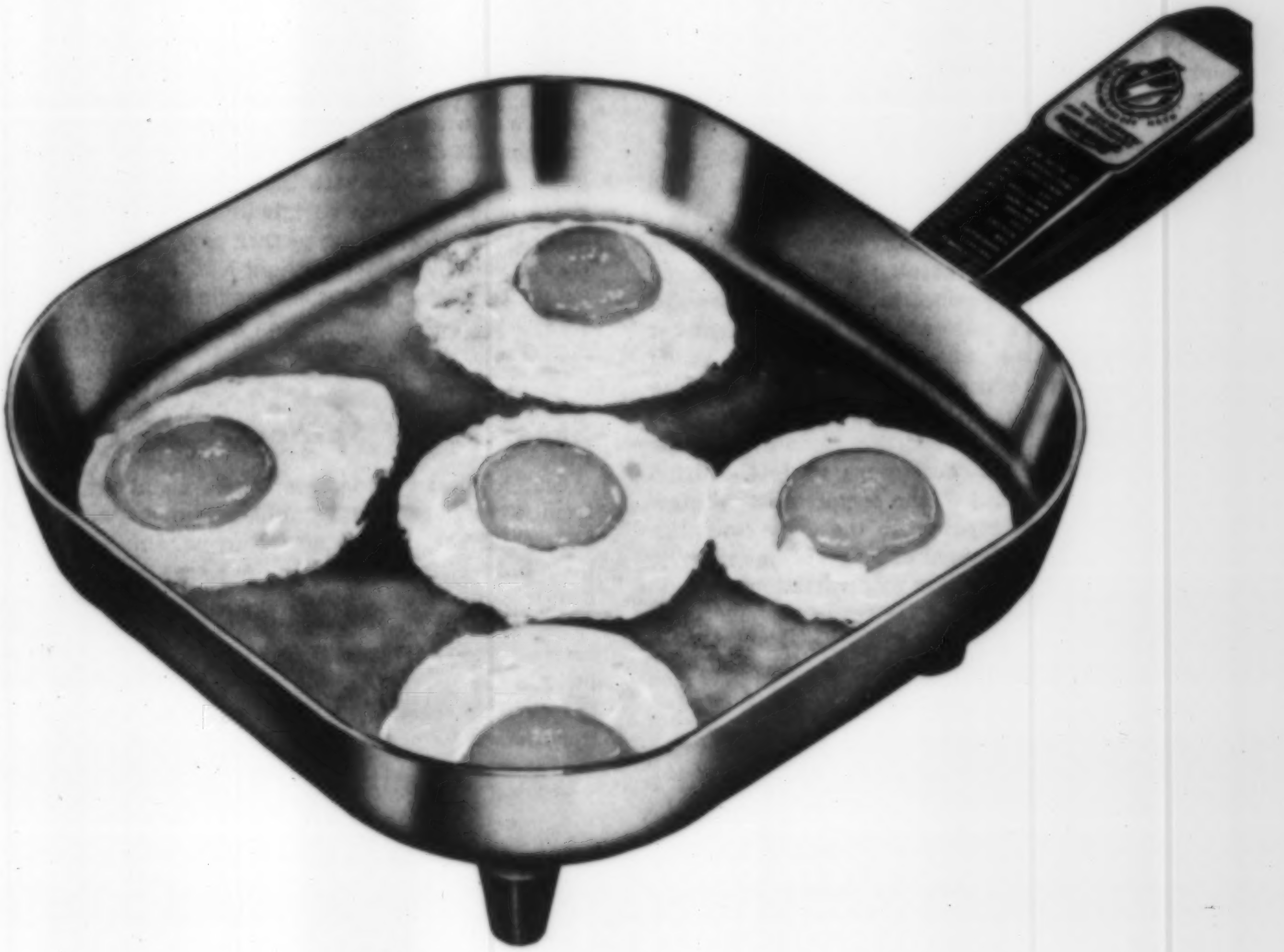
Shaft Timing Adjuster

Relative angular displacement of rotating shafts may be changed with this device which consists of a series of sprockets driven by a common endless chain. Phase angle between the two rotating shafts is determined by the position of two idler sprockets with respect to the main sprockets. By co-ordinating the change of position of the idler sprockets by means of interconnected arms, the ratio of the chain length from the driven to the driving sprocket can be varied. Thus, the phase angle between the shafts can be varied by a predetermined amount. Idler sprockets may be changed to provide variations in the phase adjustment. This device may be used to permit reversal of an internal combustion engine by changing the relative angular positions of the cam shaft and drive shaft. *Patent 2,683,993 assigned to Diamond Chain Co. by W. V. Covert.*

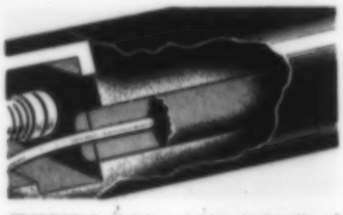
Reverse Rotation Stops

Pawls for reverse rotation stops have been designed to be insensitive to shaft speed fluctuations. Oscillation that occurs under these conditions has been minimized by locating the center of gravity at a point at which the carrier radius is intersected at right angles by a pawl radius. At this point, tangential force during rotation will have no moment arm to swing the pawl about its pivot center. Therefore, fluctuations in the tangential force occurring during shaft speed fluctuations will not rotate the pawls about their pivot centers. Holes are drilled in the pawl to fix the center of gravity at the proper





TRENTWELD stainless tubing chosen for connecting unit of new Sunbeam automatic frypan



TRENTWELD stainless tubing in handle of Sunbeam frypan

Two six-inch lengths of TRENTWELD stainless tubing form an important element of this popular new automatic frypan. One tube carries the electrical connection to the heating element embedded in the pan, and the other carries the dial connections to the thermostatic control. They make a tight, waterproof seal . . . and add strength to the bakelite handle.

You'll find more and more manufacturers specifying TRENTWELD for products ranging from frypans to heat exchangers. That's because you just can't buy better tubing than TRENTWELD, no matter what the application. TRENTWELD stainless and high-alloy tubing is a product of tube mill specialists.

And when it comes to sizes and finishes, Trent provides the widest range in the industry . . . standard sizes from 1/8″ to 40″ O.D. – larger sizes on special order. Next time you need tubing be sure and make it TRENTWELD.

Buy
U.S. Savings
Bonds

TRENTWELD

STAINLESS STEEL TUBING

TRENT TUBE COMPANY, GENERAL SALES OFFICES, EAST TROY, WISCONSIN (Subsidiary of CRUCIBLE STEEL COMPANY OF AMERICA) point. *Patent* 2,685,530 *assigned to Falk Corp. by L. W. Falk.*

Load-Sensitive Chain Drive

Damage caused by overloading or jamming of chain-drive conveyors can be prevented with the compound sprocket drive wheel described in this patent. Coupled to the drive shaft is a plate which drives the sprocket wheel through three equally spaced compression springs. Relative rotation between the drive plate and sprocket wheel is detected by a lever arm arranged to actuate a cut-off switch. Upon overload or jamming, the sprocket wheel stops while the drive plate rotates to the limit of the compression springs. The switch disconnects power to the drive until the trouble is corrected. Several drive sprockets may be used to power large conveyors with variations in synchronization smoothed out by the resilient connection. *Patent* 2,689,891 *assigned to Conveyor Engineering Co. by J. B. Silver and N. M. Harrod.*

One-Way Clutch

Frictional engagement between a pulley and shaft in one direction only is made possible by a friction-actuated ratchet working with a coil spring wrapped around a shaft. The ratchet is designed to tilt slightly when the driving pulley is rotated in one direction. When tilted, an edge of the ratchet engages a tailpiece projecting from the spring. Upon contact, the spring tightens around the driven shaft thus rotating the shaft with the pulley. In rotating the pulley in the opposite direction, the ratchet does not tilt, thereby avoiding contact with the spring tailpiece and the shaft is not driven. Originally designed as a reel drive system for motion picture projectors, the invention is suitable for other light-load drives where the automatic clutching feature would be useful. *Patent* 2,688,389 *assigned to Eastman Kodak Co. by O. Wittel and G. Wittel.*

Sheet Metal Sprags

Clutch sprags made from sheet metal are formed from a single strip and folded into an annulus to fit around the drive shaft. Narrow connecting portions between the sprags are designed to provide the proper resilience in operation. Corrugations in the sprag faces stiffen the metal and space the sprags between the races. Modifications of this construction include the use of friction shoes to reduce wear on the gripper assembly. *Patent* 2,689,633 *assigned to Borg-Warner Corp. by H. H. Turner.*

Copies of the patents briefed in this department may be obtained for 25 cents each from The Commissioner of Patents, Washington 25, D. C.

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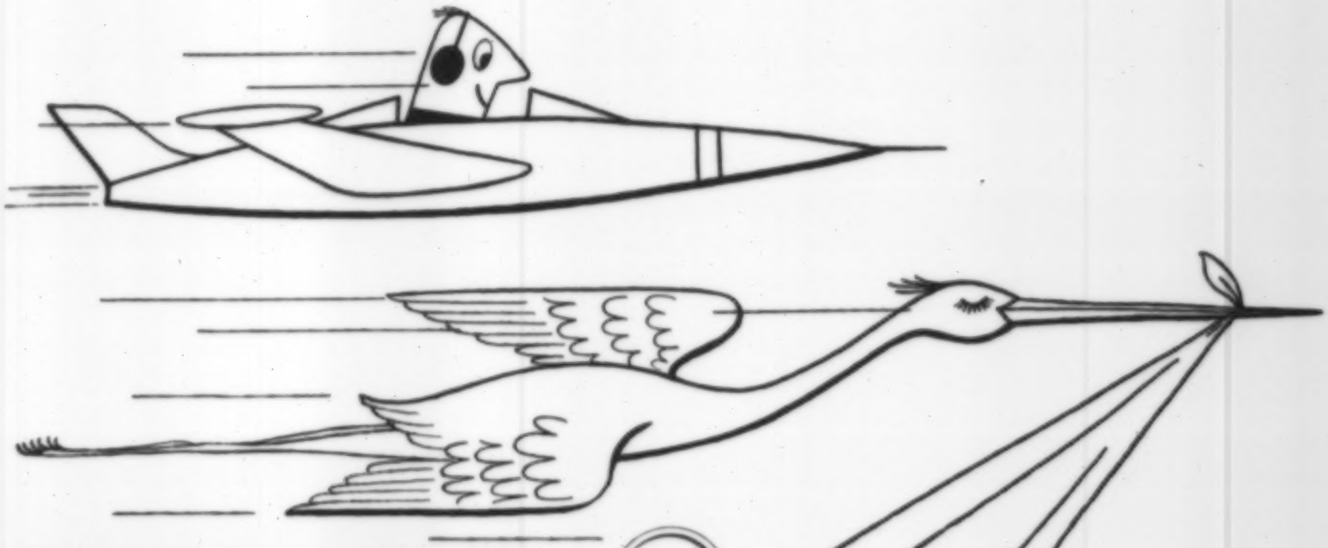

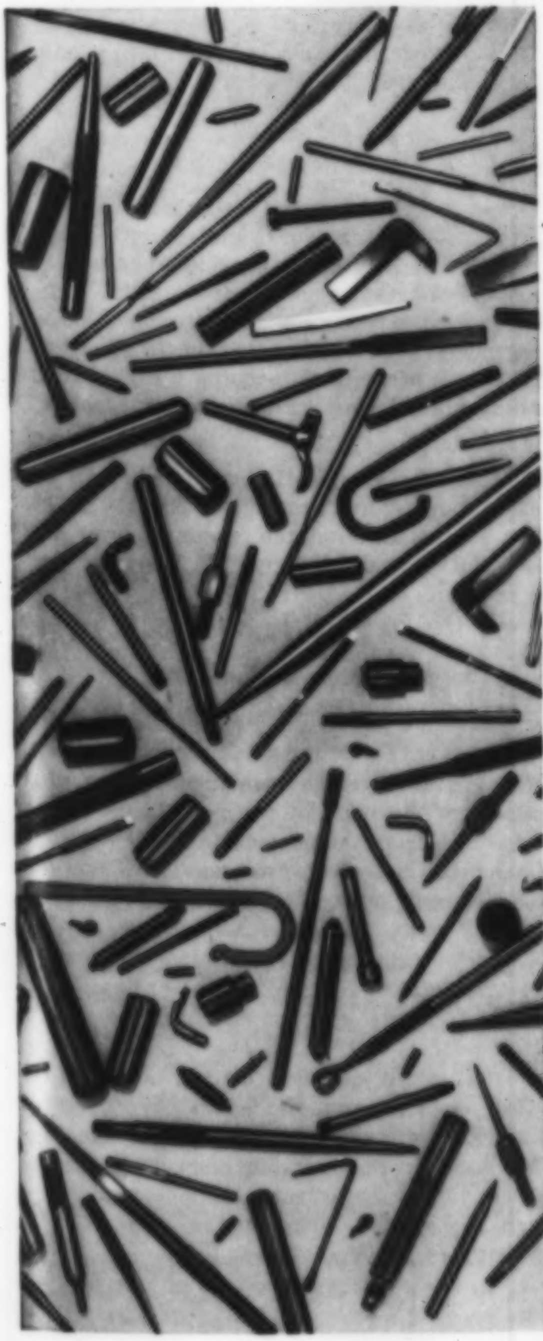

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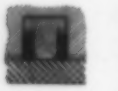

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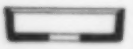

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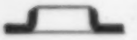

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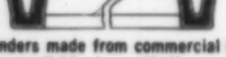

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New Machines

Materials Handling

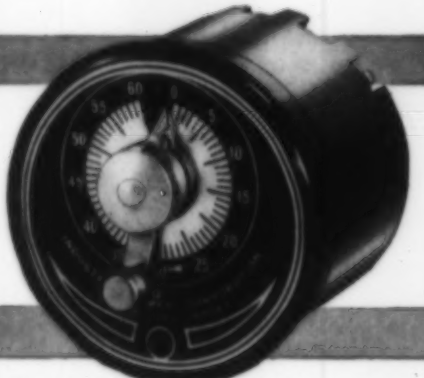
Magnetic Conveyor: Rapistan magnetic conveyor carries ferrous parts up a steep incline on ribbed-top rubber belt which travels over a magnetic field. Two 4-in. pulleys allow the unit to receive parts from production machines as low as 6 in. from the floor. Centered on the underside of the aluminum bed are two parallel pole strips bridged by permanently energized magnets which maintain the magnetic field evenly over the bed length. Tubular frame stand has two wheels which are slightly elevated. Conveyor rests on the stand while operating and can be tipped onto its wheels for easy moving. Conveyor is powered by a $\frac{1}{3}$-hp motor at belt speed of 85 fpm. Motors are available in different voltages and phases. *Rapids-Standard Co. Inc., Grand Rapids, Mich.*

Industrial Truck: High-lift platform type truck, equipped with extensible forks instead of a platform, carries loads 9 ft long and 4 ft wide. Loads are carried crosswise on the truck's pair of 41-in. forks, or the forks can be extended to 81 in. to carry the same load lengthwise. Truck has four-wheel steering and provides 113-in. lift with telescoping uprights to facilitate ceiling-high tiering. *Elwell-Parker Electric Co., Cleveland, O.*

Straddle Truck: Model MD, used to handle heavy and bulky products, has capacity of 20,000 lb. Truck has 91-hp engine, 12-in. clutch, vacuum power brakes and heavy-duty hypoid differential. Various sizes of truck accommodate loads to 78 in. high and 76 in. wide. *Hyster Co., Portland, Oreg.*

Metalworking

Gear Hobber: Compact, high-speed HoBlique gear hobbing machine is designed for mass production of helical gears. Machine combines feeding of the hob tangent to the helix of the gear being cut with automatic TriLineal feeding cycle, which provides three feed rates in series. Two successive fast-enter feeds at different rates are followed by the normal hobbing feed rate. TriLineal feed along the helix angle is hydraulically operated, eliminating possibility of lead screw error. No differential or lead cam is required, and change gear calculations are unnecessary. Hob wear is distributed over the entire length of hob. After work has been loaded, actuation of a pushbutton begins automatic cycle. Work support arm is quickly lowered and locked, at the same time work is clamped; hob rotates and climb feeds at two successive fast-enter rates, followed by normal feed; hob stops and returns rapidly through cut; support arm elevates and work unclamps. Machine is adaptable for wide range of right and left-hand helical gears up to 45-deg helix angle. Hob speeds



Time Delay Timers

Interval Timers

Re-Cycling Timers

RESET TIME TOTALIZER
HOURS
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Running Time Meters

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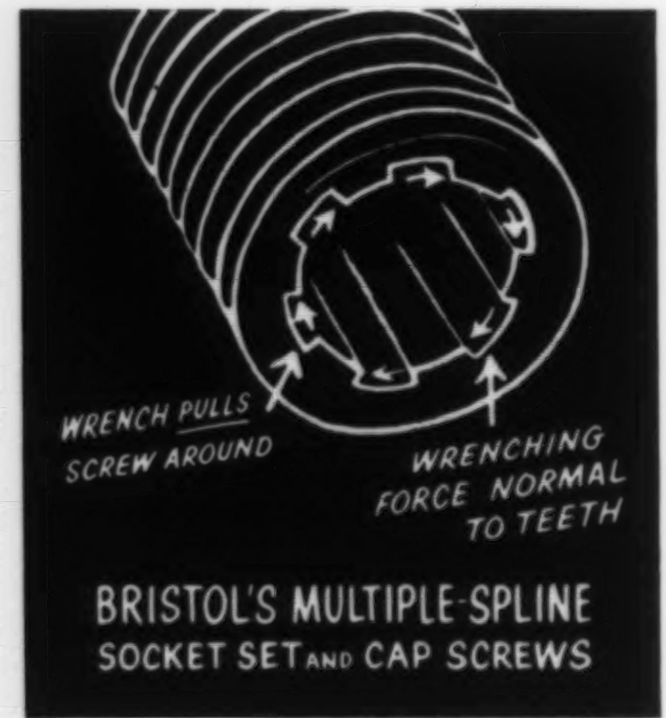
WRENCH PULLS SCREW AROUND
WRENCHING FORCE NORMAL TO TEETH
BRISTOL'S MULTIPLE-SPLINE
SOCKET SET AND CAP SCREWS

SEE HOW GEAR-LIKE TEETH in Multiple-Spline Socket enable wrench to *pull* screw around. No expanding pressure – *all* wrenching force is translated into rotary motion. Result: faster assembly, tighter wrenching for greater holding power. Bristol's Multiple-Spline Socket Screws can be wrenched thousands of times and never break or round out at high torque.

BETTER TWIST in socket screws — from elementary engineering principle

We're talking about the multiple-spline – you probably discussed it in your first year at engineering school.

It was this age-old principle, recognized as one of the best means of transmitting rotary power (used on automobile drive shafts, rear axles and airplane propeller hubs, for example), that Bristol's design engineers thought of when they set out to build a *better* socket screw.

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That's the story behind the Bristol Multiple-Spline Socket Screw – now used wherever shock and severe vibration exist . . . wherever a *better* socket screw is needed.

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A.4.12

BRISTOL'S SOCKET SCREWS

THE BRISTOL COMPANY, Socket Screw Division, Waterbury 20, Conn.

up to 550 rpm are available, and capacity is from 2¾ to 10-in. diameter, 8 to 14 NDP with 6-in. maximum face. *Gould & Eberhardt Inc., Irvington, N. J.*

Gear Grinder: Automatic, wet type No. 105 Straight Bevel Coniflex grinder produces gears up to 8½ in. pitch diameter, 1⅜ in. face width and 3 DP. All standard pressure angles can be ground. Fine pitch gears are ground directly from the solid blank; gears coarser than approximately 20 DP are ground after cutting and hardening. Machine uses two disk type grinding wheels. Grinding is done on the flat sides of the wheels, and the tooth profile shape is generated by a relative rolling motion between gear blank and grinding wheels. Once gear has been chucked in workhead, grinding cycle is automatic, including correct number of passes, in-feed of work and dressing of wheels at preselected intervals. Wheel speed control unit increases speed of wheels as the diameter decreases from dressing, thus maintaining a constant grinding surface speed. *Gleason Works, Rochester, N. Y.*

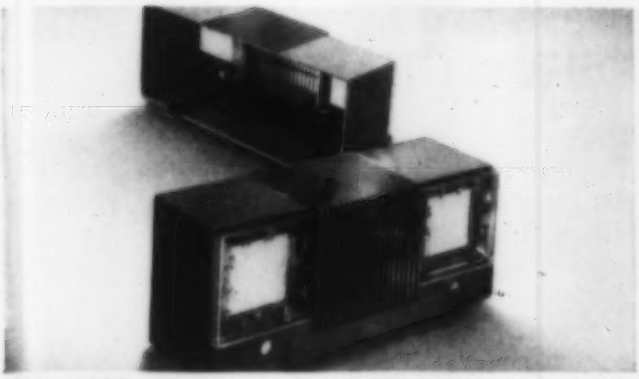
Plant Equipment

Liquid Filter: Fine as well as coarse particles are filtered from liquids through a permanent filter medium in the Delpark Up-Flo filter. Automatic, self-cleaning unit utilizes gravity to remove heavier solids before filtration of the liquid through a horizontal bar type screen. Chain-driven flights operating on a time lapse sequence pass under the filter and remove deposits from the underside of the screen and the area beneath the screen. These flights carry the particles to a cleaning device which drops swarf into a tote box for disposal. Various sizes, flow rates and capacities are available. *Industrial Filtration Co., Lebanon, Ind.*

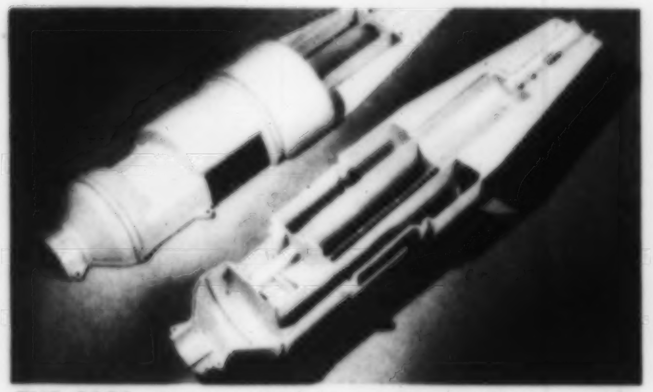
Electric Power Plants: Gen-A-Matic line of portable electric power plants includes 22 models which range from 275 and 500 w, 6 and 12 v, to 4000 w, 120 v models. Both ac and dc models are available. Operating speeds range from 2800 to 3600 rpm. Engines which operate all models are four-cycle types. Engines and generators are of equal capacity and can handle reasonable overloads. *Multi-Matic Corp., Van Nuys, Calif.*

Testing and Inspection

Motor Tester: Eight stepping or incremental motors can be tested simultaneously for any desired length of time at a frequency of either 10 or 15 pulses per second on new Incremental Motor Test Unit. Motors can be for clockwise or counterclockwise rotation. If any motor misses one pulse or step, yet continues to operate, the fault is continuously displayed on the failure indicator. Motor mount on top of test unit contains eight separate mounts, each having an adapter which permits testing two different models of motors. Basically, the test unit consists of eight separate comparators, each operating independently. If any one comparator fails, it can be removed without interrupting the test cycle of the others. *Cal-Tronics Corp., Los Angeles, Calif.*



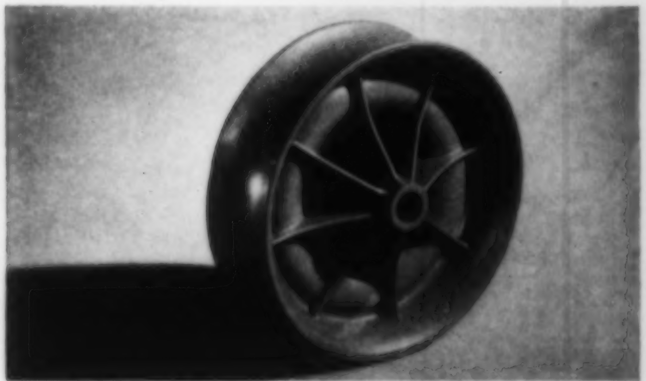
SMD-3000—the BAKELITE Styrene Plastic with the high heat distortion point of 197 deg. F. measured on an unannealed test bar ⅛ in. thick. Has same color and clarity as other BAKELITE Styrene molding materials. Warping and distortion were completely eliminated in molding these radio cabinets from SMD-3000. They showed no stress-crazing even after immersion in n-heptane. Notice fine details, glossy surfaces in these front and rear views.



TMD-5151—BAKELITE High-Impact Styrene. Has over eight times the impact strength of general purpose styrenes. (ASTM average Izod test values using notched ⅛ in. bar at 74 deg. F.). Inherently high plasticity results in fastest set-up speed available with a high-impact styrene—an important production advantage. Surface gloss is outstanding. Opaque color range is unlimited. Colors can be duplicated from blend to blend. These toy vacuum cleaner parts show intricate details possible with TMD-5151.

C-11 Plastic—An Acrylonitrile-Styrene copolymer that combines toughness with rigidity, color and gloss. Its chemical resistance fits C-11 for kitchen wares, food packaging, refrigerator parts. It withstands food acids and oils, gasoline, moth balls, soaps, detergents, carbon tetrachloride. Will not crack or craze when exposed to substances harmful to surface of many plastics. C-11 was selected for parts of the tape recorder illustrated to provide lasting, fine appearance despite exposure to constant wear and tear.

SMD-3500—BAKELITE General-Purpose Styrene. Noted for its speed in production. One manufacturer reported a 50 per cent decrease in molding cycle time plus complete elimination of sink marks. Another was able to reduce molding temperature by 50 deg. F. while gaining a faster cycle. SMD-3500 is equally serviceable for large moldings like this refrigerator crisper drawer and for the small, close-fitting syringe holder parts shown here.



TMD-2155—BAKELITE Extra-High Impact Styrene. Has an impact strength about eighteen times that of general-purpose styrenes. (ASTM average Izod test values using notched ⅛ in. bar at 74 deg. F.). Stays tough down to −13 deg. F. Has high heat distortion point, superior surface gloss, and excellent color. Economy, color, and strength are features of this lawn mower wheel molded from TMD-2155.

B

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